Installation Manual

Volume 1

YAMAHA

Installation Manual

Volume 1

General Information and Formulas

P/N: 0FMPE-G00100

MARINE ENGINES

Marine

INSTALLATION MANUAL
Volume 1

General Information and Formulas
P/N 0FMPE-G00100

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MARINE INSTALLATION MANUAL

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Section 1

INTRODUCTION

WELCOME TO THE WORLD OF YANMAR MARINE!

Yanmar Marine offers, engines, drive systems and accessories for all types of boats, from runabouts to sailboats, and from cruisers to mega yachts. In marine leisure boating, the worldwide reputation of Yanmar Marine is second to none.

Yanmar designs engines to respect nature. This means quieter engines, with minimal vibrations, cleaner than ever. All Yanmar engines designed after 1996, meet of the present emission regulations, like BSO, SAV, EPA, IMO and RCD.

ABOUT THIS MANUAL

This manual provides boat designers, naval architects, installers and builders with the instructions necessary to safely install Yanmar Marine propulsion systems. Optimum boat and engine performance are achieved when the appropriate diesel marine engine, marine gear, propeller and accessories are selected for an application.

Accurate information is required during the engine selection and space planning processes for each pleasure craft application. Numerous calculations are needed in determining vessel performance characteristics. Boat designers, naval architects, installers and builders use the data and formulas in these three volumes to provide systems that satisfactorily answer the operator's exacting requirements.

The manual is organized into three volumes. Volume 1 contains important formulas and procedures while Volumes 2 and 3 represent a comprehensive collection of critical engine, marine gear and mounting specifications.

Please note that this manual does not include guidance about the safety regulations of each country. Also, the diagrams, figures and information in this manual are subject to change in accordance with technical improvements made to our engines. Engine data and optional accessories are subject to change without notice.

REVISION HISTORY

This manual is a living document. Periodic manual revisions are published to document product improvements and changes. This practice ensures the manual has the most current information.

As manual revisions become necessary, individual pages are prepared and sent to those who need the information. If a page, or number of pages should be replaced, the replacement information is sent along with a revised **Revision Control Table.** Discard the older, obsolete information.

At times the revision involves inserting additional pages in one or more sections. Insert the new information and only the **Revision Control Table** should be replaced.

This method of revision control represents the most cost-effective solution to providing fresh, updated information as needed.

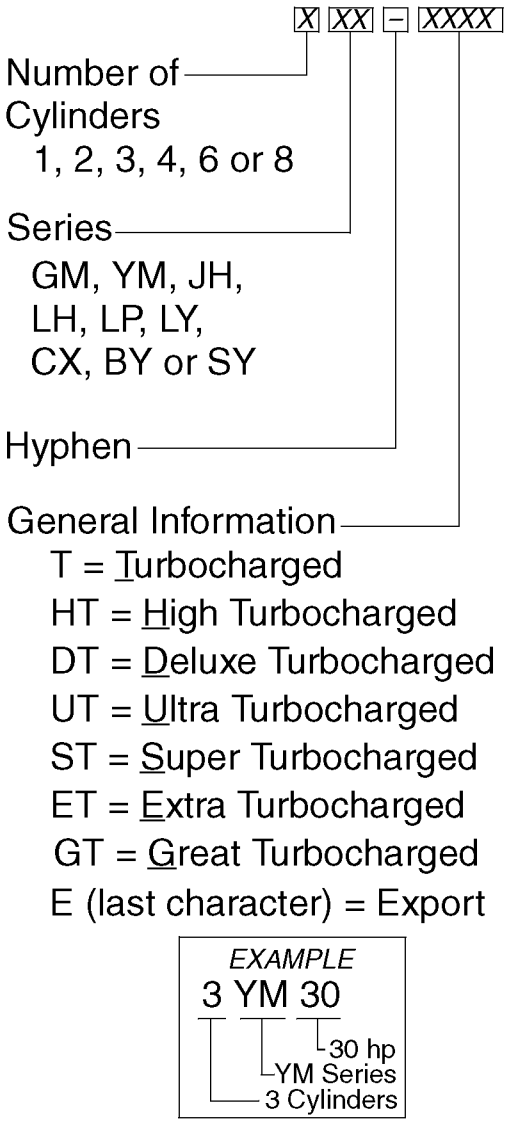
Revision Control Table

Revision Date Revision Number	New Page Numbers Involved	Remarks	Initiating Dept.
JUN 2006 Rev. 1	All	Re-release	YMU

Revision Date Revision Number	New Page Numbers Involved	Remarks	Initiating Dept.

Model Numbering System

Yanmar Marine engine models are identified by a five- to nine-character numbering system that provides specific information about each model. The first character represents the number of cylinders. The next two or three characters indicate the series. The last group of characters provide some general information about a specific model in the series. If a hyphen separates the last group of characters from the first characters, that model number is describing a turbocharged engine. A graphic explanation of this numbering system follows:



Details for each engine model are found in Volumes 2 and 3.

Section 2

SAFETY

Yanmar considers safety of great importance and recommends that anyone that comes into close contact with its products, such as those who install, operate, maintain or service Yanmar products, exercise care, common sense and comply with the safety information in this manual. We have provided the safety statements you should be aware of when you design an application for a Yanmar marine engine. Please note that the language presented in each safety message is as it appears in various Yanmar Marine *Operation Manuals* and *Service Manuals*.

This safety alert symbol appears with most safety statements. It means attention, become alert, your safety is involved! Please read and abide by the message that follows the safety alert symbol.

⚠ DANGER

Danger (the word "DANGER" is in white letters with a red rectangle behind it) - indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. Danger is limited to the most extreme situations.

0000001en

⚠ WARNING

Warning (the word "WARNING" is in black letters with an orange rectangle behind it) – indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

0000001en

⚠ CAUTION

Caution (the word "CAUTION" is in black letters with a yellow rectangle behind it) – indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.

0000001en

CAUTION

Caution *without the safety alert symbol* indicates a potentially hazardous situation that can cause damage to the engine, personal property and / or the environment or cause the engine to operate improperly.

0000001enMarine

SAFETY PRECAUTIONS

⚠ DANGER

EXPLOSION HAZARD!

- Keep the area around the battery well-ventilated. While the engine is running or the battery is charging, hydrogen gas is produced which can be easily ignited.
- Keep sparks, open flame and any other form of ignition away while the engine is running or battery is charging.
- Failure to comply will result in death or serious injury.

0000003en

⚠ DANGER

SCALD HAZARD!

- NEVER remove the heat exchanger cap (coolant cap) if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the heat exchanger cap.
- Securely tighten the heat exchanger cap after you check the heat exchanger. Steam can spurt out during engine operation if the cap is loose.
- ALWAYS check the level of engine coolant by observing the reserve tank.
- Failure to comply will result in death or serious injury.

0000002enTrans

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- NEVER use diesel fuel as a cleaning agent.
- Failure to comply will result in death or serious injury.

0000012en

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.
- NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.
- Wipe up any spills immediately.
- Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.
- Failure to comply will result in death or serious injury.

0000009en

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- NEVER remove the fuel cap with the engine running.
- Failure to comply will result in death or serious injury.

0000011en

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Only use the key switch to start the engine.
- NEVER jump-start the engine. Sparks caused by shorting the battery to the starter terminals may cause a fire or explosion.
- Failure to comply will result in death or serious injury.

0000004en

⚠ DANGER

EXPLOSION HAZARD!

- NEVER check the remaining battery charge by shorting out the terminals. This will result in a spark and may cause an explosion or fire. Use a hydrometer to check the remaining battery charge.
- If the electrolyte is frozen, slowly warm the battery before you recharge it.
- Failure to comply will result in death or serious injury.

0000007en

⚠ DANGER

CRUSH HAZARD!

NEVER stand under hoisted engine. If the hoist mechanism fails, the engine will fall causing serious injury or death.

Failure to comply will result in death or serious injury.

0000008enMarine

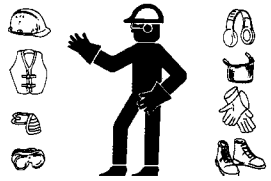
⚠ WARNING

SEVER HAZARD!

- Keep hands and other body parts away from moving / rotating parts such as the flywheel or PTO shaft.
- Wear tight fitting clothing and keep your hair short or tie it back while the engine is running.
- Remove all jewelry before you operate or service the engine.
- NEVER start the engine in gear. Sudden movement of the engine and / or vessel could cause death or serious personal injury.
- NEVER operate the engine without the guards in place.
- Before you start the engine make sure that all bystanders are clear of the area.
- Keep children and pets away while the engine is operating.
- Check before starting the engine that any tools or shop rags used during maintenance have been removed from the area.
- Failure to comply could result in death or serious injury.

0000002enMarine

⚠ WARNING



EXPOSURE HAZARD!

- Wear personal protective equipment such as gloves, work shoes, eye and hearing protection as required by the task at hand.
- NEVER wear jewelry, unbuttoned cuffs, ties or loose-fitting clothing when you are working near moving / rotating parts such as the cooling fan, flywheel or PTO shaft.
- ALWAYS tie back long hair when you are working near moving / rotating parts such as a cooling fan, flywheel, or PTO shaft.
- NEVER operate the engine while wearing a headset to listen to music or radio because it will be difficult to hear the alert signals.
- Failure to comply could result in death or serious injury.

0000005en

⚠ WARNING

EXHAUST HAZARD!

- NEVER block windows, vents, or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.
- Make sure that all connections are tightened to specifications after repair is made to the exhaust system.
- Failure to comply could result in death or serious injury.

0000003enmarine

⚠ WARNING

HIGH-PRESSURE HAZARD!

- Avoid skin contact with the high-pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High-pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high-pressure fuel spray, obtain prompt medical treatment.
- NEVER check for a fuel leak with your hands. ALWAYS use a piece of wood or cardboard. Have your authorized Yanmar industrial engine dealer or distributor repair the damage.
- Failure to comply could result in death or serious injury.

0000008en

⚠ WARNING

ENTANGLEMENT HAZARD!

- Stop the engine before you begin to service it.
- NEVER leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.
- If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.
- Failure to comply could result in death or serious injury.

0000010en

⚠ WARNING

BURN HAZARD!

- Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.
- Failure to comply could result in death or serious injury.

0000016en

⚠ WARNING

BURN HAZARD!

- If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.
- ALWAYS wear eye protection.
- Failure to comply could result in death or serious injury.

0000011en

⚠ WARNING

ALCOHOL AND DRUG HAZARD!

- NEVER operate the engine while you are under the influence of alcohol or drugs.
- NEVER operate the engine when you are feeling ill.
- Failure to comply could result in death or serious injury.

0000004en

⚠ WARNING

BURN HAZARD!

- Keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.
- Failure to comply could result in death or serious injury.

0000015en

⚠ WARNING

FIRE HAZARD!

- Undersized wiring systems can cause an electrical fire.
- Failure to comply could result in death or serious injury.

0000027en

⚠ CAUTION

FLYING OBJECT HAZARD!

- ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.
- Failure to comply may result in minor or moderate injury.

0000003en

CAUTION

- Only use diesel fuels recommended by Yanmar for the best engine performance, to prevent engine damage and to comply with EPA warranty requirements.
- Only use clean diesel fuel.

0000004enBY

CAUTION

NEVER attempt to adjust the low or high idle speed limit screw. This may impair the safety and performance of the engine and shorten its life. If adjustment is ever required, see your authorized Yanmar marine dealer or distributor.

0000045enMarine

CAUTION

If any problem is noted during the visual check, the necessary corrective action should be taken before you operate the engine.

0000021en

CAUTION

The illustrations and descriptions of optional equipment in this manual, such as the operator's console, are for a typical engine installation. Refer to the documentation supplied by the optional equipment manufacturer for specific operation and maintenance instructions.

0000018en

CAUTION

If any indicator illuminates during engine operation, stop the engine immediately. Determine the cause and repair the problem before you continue to operate the engine.

0000029en

CAUTION

- NEVER overfill the engine with engine oil.
- ALWAYS keep the oil level between the upper and lower lines on the oil cap / dipstick.

0000015en

CAUTION

For maximum engine life, Yanmar recommends that when shutting the engine down, allow the engine to idle, without load, for five minutes. This will allow the engine components that operate at high temperatures, such as the turbocharger (if equipped) and exhaust system, to cool slightly before the engine itself is shut down.

0000008en

CAUTION

NEVER use an engine starting aid such as ether. Engine damage will result.

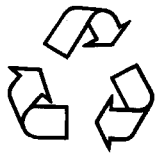
0000009en

CAUTION

NEVER engage the starter motor while the engine is running. This may damage the starter motor pinion and / or ring gear.

0000012en

CAUTION



- ALWAYS be environmentally responsible.
- Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.
- NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.
- Failure to follow these procedures may seriously harm the environment.

0000013en

CAUTION

If the fuel filter / water separator is positioned higher than the fuel level in the fuel tank, water may not drip out when the fuel filter / water separator drain cock is opened. If this happens, turn the air vent screw on the top of the fuel filter / water separator 2-3 turns counterclockwise.

Be sure to tighten the air vent screw after the water has drained out.

0000025en

CAUTION

NEVER turn off the battery switch (if equipped) or short the battery cables during operation. Damage to the electric system will result.

0000061en

CAUTION

NEVER move the adjustment nuts without using a hoist to take the pressure off the engine mount. Failure to comply may cause damage to the stud and nut threads.

0000084en

CAUTION

Excessive vibration may cause damage to the engine, marine gear, hull and on-board equipment. In addition, it causes noticeable passenger and crew discomfort. Carefully select engine mounts and propellers when you design Yanmar marine engine applications.

0000085en

CAUTION

Sea trials can only be performed safely when the vessel is adequately manned. Do not attempt to collect and record performance data while operating a vessel alone.

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Section 3

ENGINE SELECTION GUIDE

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MAIN CONSIDERATIONS

Selecting the ideal propulsion system for a vessel is a process that requires special analysis. Boat manufacturers generally specify a range of propulsion requirements for specific vessels. Selecting a propulsion system within the manufacturer's parameters involves meeting specific manufacturer's requirements while addressing the desired performance characteristics of those individuals who use the vessel.

Overview

One user's performance requirements for a particular vessel might differ from those of another user's expectations for a vessel of the same dimensions. Because of the differences in requirements by the users, re-power projects do not automatically imply replacing an existing engine, marine gear and propeller with similar equipment. Each project (re-power or original equipment) is unique.

Operating range and economy are often the first items explored. These factors are used to determine the initial investment costs and an acceptable operating budget.

After identifying the desired operating range, available initial costs and fuel economy requirements, the primary considerations are vessel purpose, hull design, hull size and weight and desired performance characteristics. Understanding these factors is necessary when selecting the propulsion system.

Vessels larger than approximately 6.7 m (22 ft) might be powered with a twin-screw configuration. Twin-screw applications have advantages and disadvantages, as do single-screw applications. Consideration must be given to these advantages and disadvantages as part of the engine selection process.

Speed and acceleration performance characteristics are driven by the user's needs in that area. Ski boats, for example, might require favorable acceleration curves, while racing boats might best be served with enhanced top speed. Power output requirements are driven by the vessel's mass and need for speed.

Specifying the marine gear and propeller requires attention to the desired performance characteristics.

Re-Power Projects

Manufacturers generally specify propulsion equipment in terms of minimum and maximum weight and horsepower. These parameters often represent a wide range of possibilities. Because a vessel's purpose might change, re-power projects can involve increasing or decreasing engine horsepower.

Range

Range is a function of engine efficiency and fuel capacity. It can be defined as the distance the vessel can be expected to travel with the maximum amount of fuel available on board. Generally, the larger the fuel tank capacity, the greater the range.

Economy

Fuel economy is a function of engine efficiency. It can be defined as the cost of exhausting the vessel's fuel capacity and full range.

The most efficient engines move a vessel further on a unit of fuel than less efficient engines. Slower vessels are generally more economical to operate.

Vessel Purpose

The purpose for which a vessel is used must be determined as part of the selection process. This three-volume manual primarily addresses pleasure vessel applications.

Pleasure Vessels

Pleasure vessels range in size from runabouts as small as 5 m (16.5 ft) to larger crafts in excess of 15 m (50 ft). Because these vessels are classified as pleasure craft, they generally are burdened with relatively light workloads. Pleasure craft either have short-duty cycles, small power requirements or both of these elements.

Pleasure vessels require a variety of different propulsion systems, depending on the operating environment and performance needs. Ski boats, fishing boats, cabin cruisers and sailboats might be operated in lakes, rivers or oceans. Like their work vessel counterparts, pleasure craft might be operated in a variety of sea conditions.

Work Vessels

Work vessels range in size from fishing charter boats as small as 5 m (16.5 ft) to large fishing trawlers larger than 15 m (50 ft). Because these vessels are classified as work vessels, they generally are burdened with heavy workloads. Work vessels either have long-duty cycles, high-power requirements or both of these elements. This three-volume manual primarily addresses pleasure vessel applications.

Work vessels require vastly different propulsion systems, depending on the type of commercial or government activity for which the watercraft is used. Water taxis, rescue vessels, tow boats and others might be operated in lakes, rivers or oceans. Attention must be given to sea conditions (rough, oceanic vs. calm, inland waterways).

Hull Types

Watercraft are generally built in one of three basic design categories:

- Planing
- Displacement
- Semi-displacement

Each hull type exhibits performance characteristics with distinctive properties, each different from the others.

Planing Hulls

Planing hulls are driven up on top of the water rather than being driven through the water **(Figure 3-1)**.

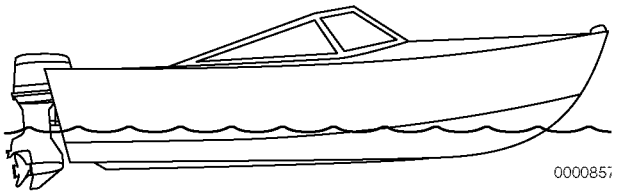

Figure 3-1

They are relatively fast hulls and typically have flat bottoms near the stern. These hulls are typically less seaworthy in high seas than displacement or semi-displacement hulls. When equipped with high power, high rpm propulsion systems, planing hulls offer extremely high speed capabilities. Some speeds have been measured at over 320 km/h (200 mph).

Displacement Hulls

Displacement hulls are driven through the water, rather than being pushed up on top of the water **(Figure 3-2)**.

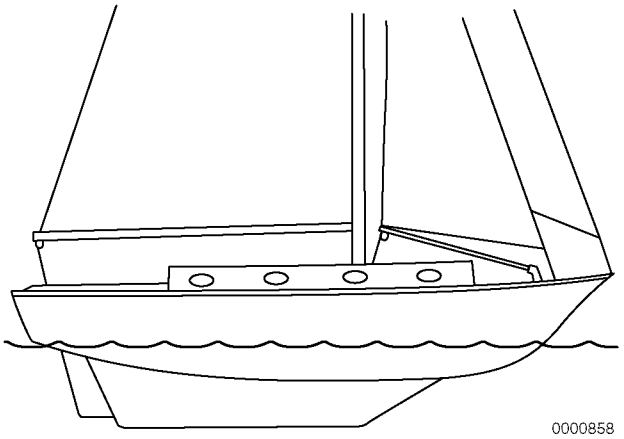

Figure 3-2

They are relatively slow hulls but can accommodate highly powerful propulsion systems and have useful cargo and towing capacity, compared to planing designs. The approximate maximum hull speed is defined as:

$$(1.34)\sqrt[2]{LWL} = Z$$

Where:

LWL = Vessel length in feet (at waterline)

Z = Maximum hull speed in knots

While additional horsepower can help maintain hull speed in adverse weather conditions, it cannot improve the maximum hull speed of displacement hulls. These hulls are typically very stable in high seas. When equipped with high power propulsion systems, displacement hulls offer favorable towing ability.

Semi-Displacement

Semi-displacement hull designs represent a compromise between planing and displacement hull designs **(Figure 3-3)**.

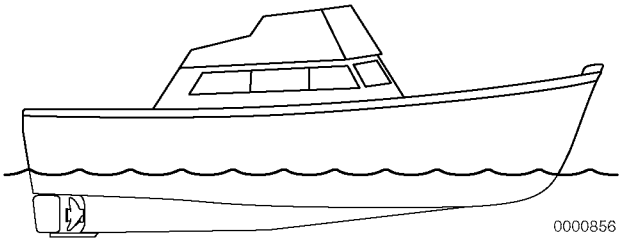

Figure 3-3

These hulls are slightly faster than displacement designs but more stable than planing hulls. While additional horsepower can help maintain hull speed in adverse weather conditions, it cannot improve the maximum hull speed of semi-displacement hulls. This hull design offers favorable cargo and towing capacity compared to planing designs.

Hull Displacement

Hull displacement is defined as the weight of water displaced by the total mass of a vessel. The greater the vessel hull displacement, the greater the horsepower required to move the vessel.

Displacement and semi-displacement hulls are most often driven by inboard engines. The engine power, marine gear, propeller and the number of engines are all a function of the hull displacement and the total power requirements.

Total maximum hull displacement is the sum total all material and personnel mass on board:

- Vessel displacement (empty weight)
- Engine
- Marine gear
- Ancillary equipment
- Cargo and provisions
- Fuel storage
- Passengers

When determining the horsepower requirements, consider the total hull displacement of the vessel. Determining the horsepower required to achieve maximum hull speed, given a specific hull displacement, involves calculating the speed-to-length ratio (SL). The horsepower requirement is typically calculated by the vessel manufacturer and published in their literature in the form of a power range.

Performance Characteristics

Desired speed and acceleration are the determining factors when selecting the engine, marine gear and the propeller. *See General on page 5-3 in Propeller Selection.*

High power output at high rpm offers the best speed performance. High power output at relatively lower rpm provides the best cargo handling and towing performance.

Twin-Screw Applications

Most pleasure craft of modest dimensions and displacement or semi-displacement hull design, are candidates for single-screw applications. Larger vessels and fast planing vessels, might best serve their users with twin-screw applications. The following table illustrates the advantages and disadvantages of twin-screw and single-screw applications.

	Twin-Screw Applications	Single-Screw Applications
Advantages	• Greater maneuverability • Greater speed and power • Safety after one engine loss	• Greater fuel economy • Greater range
Disadvantages	• Greater fuel consumption • Shorter range	• Less maneuverable • Slower and less powerful • No redundancy for engine loss

Marine Gear

Selection of a marine gear requires consideration of torque limits, rpm requirements and propeller selection. Some Yanmar marine engines are equipped with marine gears and drives. Others can be matched with that equipment separately. In any case, the selection of this equipment is dependent upon gear reduction requirements, rpm and the propeller. For more details on propeller requirements, *see Propeller Selection on page 5-1*.

Inboard marine gears are installed in three different drive configurations:

- Parallel **(Figure 3-4)**
- Angle **(Figure 3-5)**
- V-drive **(Figure 3-6)**

Parallel Drive

The output shaft of the marine gear is parallel to the crankshaft **(Figure 3-4)**. The engine is installed at an angle. This configuration offers the greatest engine efficiency but might not provide the best possible hull efficiency.

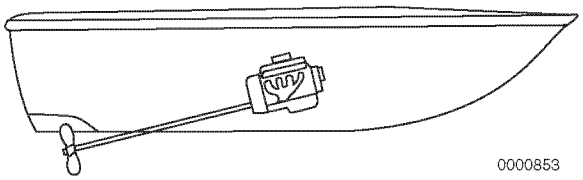

Figure 3-4

Angle Drive

This configuration is sometimes called the down-angle drive system. The output shaft of the marine gear is inclined at 7-10° to the crankshaft **(Figure 3-5)**. The gentle inclination of the engine / marine gear package reduces space requirements in the engine room. Some power loss is noted because of the angle.

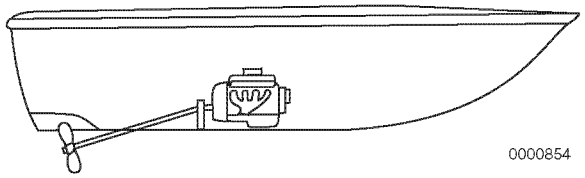

Figure 3-5

V-Drive

In this configuration, the output shaft of the marine gear forms a V-shape with the input shaft. The propeller shaft leads aft compared with propeller angle drive and the engine is installed with the driveshaft facing forward **(Figure 3-6)**. The advantage of this type of marine gear is that a stern engine installation leaves more room for living space. The disadvantage is the difficulty in selecting flexible engine mounts and the comparatively large loss in horsepower.

See *Engine Mounting* on *page 4-1* for details. The following table illustrates the advantages and disadvantages of each drive configuration.

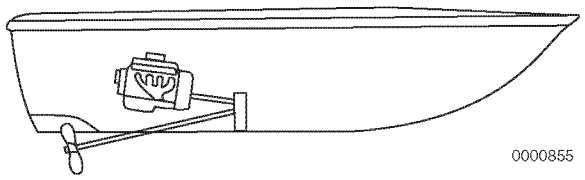

Figure 3-6

Drive System Analysis

	Parallel Drive	Angle Drive	V-Drive
Advantage	Least horsepower loss	Requires less space in engine room	Most living space in cabin
Disadvantage	Requires most space in engine room	Slight horsepower loss	Horsepower loss at extreme angles

Power Rating Standard

The output of Yanmar's main propulsion engines for pleasure boat use is rated according to the Yanmar Industrial Standard (YIS).

The output testing conditions of the YIS are as follows:

Standard Atmospheric Condition (Ambient Condition)

	Unit	YIS
Atmospheric pressure	kPa (mmHg)	100 (750)
Temperature	°K (°C)	298 (25)
Relative humidity	%	30
Inlet seawater temperature	°K (°C)	303 (30)

Diesel Fuel, Japanese Industrial Standard (JIS), K2204 No. 2

Flash Point	Above 50°C (122°F)
Distillation Temperature (90 point)	350°C maximum
Flow Point	Below -7.5°C
Carbon Residue on 10% Residuum	Mass below 0.10%
Cetane Number	Above 45
Kinematic Viscosity 30°C	2.5 cSt Minimum
Sulfur Content	Below 0.05%

Lubrication Oil

Engine Type	SAE Number	API Service
Naturally Aspirated	10W30	CC Class
Turbocharged	15W40	CD Class

Equipment Attached to the Engine When Testing Output

In the YIS, the engine output is measured with the following equipment installed. There is no need to consider any loss of output due to these engine attachments.

- Fuel feed pump
- Cooling water pump
- Alternator
- Intake air silencer

Output Indication

Shown in kW and hp metric.

Yanmar conversion: 0.7355 kW=1 hp metric

Rated Output

Continuous rating output: The output that the engine can produce continuously at a fixed engine speed under the standard atmospheric condition.

Maximum rating output: The maximum output that the engine, with limited fuel injection and engine revolutions, can produce at a fixed engine speed under the standard atmospheric condition.

Adjusting Output (De-rating)

The engine output rating for Yanmar pleasure boat series engines is specified at the following standard atmospheric conditions:

Atmospheric Pressure (P_r): 100 kPa (750 mmHg)
Ambient Temperature (T_r): 298°K (25°C)
Relative Humidity (Φ_x): 30%

If the operating conditions are different from the standard atmospheric conditions, use the following formulas to adjust the engine output.

Formula 1: Formula for adjusting output (P)

$$P = kP_o$$

P :	Adjusted output (Output under standard atmospheric conditions)	kW
P_o :	Actually measured output	kW
k :	Coefficient of adjustment	

Formula 2: Calculating the coefficient of adjustment (k)

$$k = (f_a)^{f_m}$$

k :	Coefficient of adjustment
f_a :	Coefficient of atmospheric environment
f_m :	Coefficient of adjustment for air-fuel ratio

Formula 3: Calculating the coefficient of atmospheric environment (f_a)

The coefficient of atmospheric environment (f_a) varies with conditions (atmospheric pressure, ambient temperature and relative humidity) of the air taken in by the engine.

- Natural aspirated engine.

$$f_a = \left(\frac{P_r - \Phi_r \times P_{sr}}{P_x - \Phi_x \times P_{sx}}\right)\left(\frac{T_x}{T_r}\right)^{0.7}$$

- Turbocharged engine.

$$f_a = \left(\frac{P_r - \Phi_r \times P_{sr}}{P_x - \Phi_x \times P_{sx}}\right)^{0.7}\left(\frac{T_x}{T_r}\right)^{1.5}$$

f_a :	Coefficient of atmospheric environment	
P_r :	Standard atmospheric pressure	kPa (mmHg)
Φ_r :	Relative humidity under standard atmospheric condition	
P_{sr} :	Saturated vapor pressure under standard atmospheric condition	kPa (mmHg)
P_x :	Atmospheric pressure in operating environment	kPa (mmHg)
Φ_x :	Relative humidity in operating environment	%
P_{sx} :	Saturated vapor pressure in operating environment	kPa (mmHg)
T_x :	Intake air temperature in operating environment	°K (°C)
T_r :	Intake air temperature under standard atmospheric condition	°K (°C)

Saturated Vapor Pressure in Relation to Atmospheric Temperature Chart

Ambient Temperature			Saturated Vapor Pressure		
°K	°C	°F	kPa	mmHg	in.Hg
293	20	68	2.337	17.53	0.6902
295	22	72	2.642	19.82	0.7803
297	24	75	2.983	22.38	0.8811
298	25	77	3.172	23.80	0.9370
299	26	79	3.360	25.21	0.9925
300	27	81	3.560	26.74	1.0528
301	28	82	3.779	28.35	1.1161
303	30	86	4.243	31.83	1.2531
305	32	90	4.755	35.67	1.4043
307	34	93	5.319	39.90	1.5709
309	36	97	5.941	44.57	1.7547
311	38	100	6.625	49.70	1.9567
313	40	104	7.377	55.34	2.1787
315	42	108	8.201	61.52	2.4220
317	44	111	9.103	68.29	2.6886
319	46	115	10.088	75.68	2.9795
321	48	118	11.164	83.75	3.2972
323	50	122	12.338	92.56	3.6441

Formula 4: Calculating the coefficient of adjustment for air-fuel ratio (f_m)

Note: Air-fuel ratio is the mass ratio of air and fuel supplied to the engine cylinder.

$$f_m = 0.036 q_c - 1.14$$

$$q_c = \frac{q}{r}$$

r : Ratio of turbocharger outlet pressure to inlet pressure
- Naturally aspirated engine: 1
- Turbocharged engine: 1.2 - 2.0 (varies according to revolution speed and output)

q_c : Air-fuel ratio (mg/L-cycle)

q : Fuel supply quantity per cycle for engine displacement volume of one liter (mg/L-cycle)

$$q = \frac{\text{Specific fuel consumption} \times \text{Output (kW)} \times 1000}{60 \times \frac{\text{Engine speed}}{2} \times \text{Displacement}}$$

Specific fuel consumption: g/kW

Displacement: liter

Note: The coefficient of air-fuel ratio (f_m) is 0.3 when the air-fuel ratio (q_c) is less than 40 mg/L-cycle, and constant at 1.2 if the air-fuel ratio (f_m) exceeds 65 mg/L-cycle **(Figure 3-7)**.

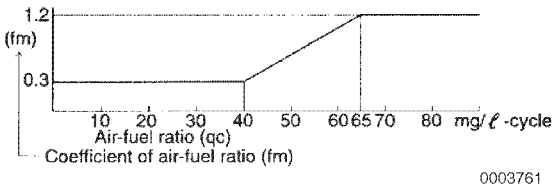

Figure 3-7

Calculating Engine Output Adjustment

The 6LY-STE engine is used for this example. Under standard atmospheric conditions the engine has the following characteristics:

Maximum Output (at 3300 rpm): 257.4 kW

Specific Fuel Consumption (at 3300 rpm): 252 g/kW-h

The following values are from the standard atmospheric conditions presented in the *Saturated Vapor Pressure in Relation to Atmospheric Temperature Chart on page 3-9* and will be used in this example.

Atmospheric Pressure (P_r): 100 kPa (750 mmHg)
Intake Air Temperature (T_r): 298°K (25°C)
Relative Humidity (Φ_r): 30% = 0.3
Saturated Vapor Pressure (P_{sr}): 3.172 kPa (23.80 mmHg)

In this exercise we need to calculate the maximum output for the 6LY-STE under these operating atmospheric conditions:

Atmospheric Pressure (P_x): 96 kPa (720 mmHg)
Intake Air Temperature (T_x): 323°K (50°C)
Relative Humidity (Φ_x): 60% = 0.6
Saturated Vapor Pressure (P_{sx}): 12.338 kPa (92.56 mmHg)

Calculation of Engine Output Adjustment:

In Formula 1 we substitute 257.4 kW for "P." Note that we need to determine the value of "k."

$$P = kP_o \Rightarrow P_o = \frac{257.4}{k}$$

To determine the value of "k" we will use Formula 2 and 3. Recall that Formula 2 is:

$$k = (f_a)^{f_m}$$

In Formula 3, we will substitute the values for Standard Atmospheric Conditions and Operating Atmospheric Conditions presented in the assumptions.

$$f_a = \left(\frac{P_r - \Phi_r \times P_{sr}}{P_x - \Phi_x \times P_{sx}}\right)^{0.7}\left(\frac{T_x}{T_r}\right)^{1.5}$$

$$f_a = \left(\frac{100 - 0.3 \times 3.172}{96 - 0.6 \times 12.338}\right)^{0.7} \times \left(\frac{323}{298}\right)^{1.5} = 1.218$$

Recall that Formula 4 is:

$$fm = 0.036q_c - 1.14$$

For turbocharged engine:

$$q_c = \frac{q}{r}$$

$$r = 1.2 \sim 2.0$$

$$q_c = \frac{q}{1.8}$$

$$q = \frac{\text{Specific fuel consumption} \times \text{Output (kW)} \times 1000}{60 \times \frac{\text{Engine speed}}{2} \times \text{Displacement}}$$

$$= \frac{252 \times 257.4 \times 1000}{60 \times \frac{3300}{2} \times 5.184} = 126.39 \text{mg/L-cycle}$$

$$q_c = \frac{126.39}{1.8} = 70.22$$

Substituting value for q_c back into Formula 4:

$$f_m = 0.036 \times 70.22 - 1.14 = 1.39$$

Substituting f_a and f_m back into Formula 2:

$$k = fa^{fm}$$

$$= 1.218^{1.39}$$

$$k = 1.32$$

Substituting value “k” back into Formula 1:

$$P_o = \frac{P}{k}$$

$$= \frac{257.4}{1.32}$$

$$P_o = 195\text{kW}$$

Altitude Correction for Atmospheric Pressure (P_x)

Formula:

$$P_x = P_r(1 - 0.00002257h)$$

P_x :	Atmospheric pressure at altitude, h (m)	kPa (mmHg)
P_r :	Standard atmospheric pressure at 0 (zero meters above seal level)	100kPa (750 mmHg)
h :	Altitude	m

Calculation of Altitude Correction for Atmospheric Temperature (T_x)

Formula:

$$T_x = T_r - (1 - 0.0065h)$$

T_x :	Atmospheric temperature at altitude, h	C°
T_r :	Standard atmospheric temperature at 0 (zero meters above sea level)	25°C
h :	Altitude	m

Relationship between Atmospheric Pressure and Temperature

Altitude (m)	Atmospheric Pressure kPa (mmHg)	Atmospheric Temperature °K (°C)	Altitude m	Atmospheric Pressure kPa (mmHg)	Atmospheric Temperature °K (°C)
0	100.0 (750)	298.0 (25.0)	1400	84.5 (634)	288.9 (15.9)
100	98.8 (741)	297.4 (24.4)	1600	82.5 (619)	287.6 (14.6)
200	97.7 (732)	296.7 (23.7)	1800	80.5 (604)	286.3 (13.3)
400	95.4 (716)	295.4 (22.4)	2000	78.5 (589)	285.0 (12.0)
600	93.1 (698)	294.1 (21.1)	2500	73.7 (553)	281.8 (8.8)
800	90.9 (682)	292.8 (19.8)	3000	69.3 (520)	278.5 (5.5)
1000	88.7 (665)	291.5 (18.5)	3500	65.0 (488)	275.3 (2.3)
1200	86.6 (650)	290.2 (17.2)	4000	60.9 (457)	272.0 (-1)

Obtaining Relative Humidity by Dry and Wet Bulb Hydrometer

Note: Relative humidity is obtained from the following table when the wet bulb is not frozen.

Dry Bulb K (t)	Difference between dry bulb and wet bulb K-K' (t-t')										
	273.0 (0.0)	273.5 (0.5)	274.0 (1.0)	274.5 (1.5)	275.0 (2.0)	275.5 (2.5)	276.0 (3.0)	276.5 (3.5)	277.0 (4.0)	277.5 (4.5)	278.0 (5.0)
313 (40)	100	97	94	91	88	85	82	79	76	73	71
308 (35)	100	97	93	90	87	83	80	77	74	71	68
303 (30)	100	96	92	89	85	82	78	75	72	68	65
298 (25)	100	96	92	88	84	80	76	72	68	65	61
293 (20)	100	95	91	86	81	77	73	68	64	60	56
288 (15)	100	95	89	84	78	73	68	63	58	53	48
283 (10)	100	93	87	81	74	68	62	56	50	44	38
278 (5)	100	92	84	76	68	60	53	46	38	31	24
273 (0)	100	90	80	70	60	50	40	31	21	12	3
268 (-5)	100	87	74	61	48	35	22	9			
263 (-10)	100	82	64	47	29	12					

Dry Bulb K (t)	Difference between dry bulb and wet bulb K-K' (t-t')									
	278.5 (5.5)	279.0 (6.0)	279.5 (6.5)	280.0 (7.0)	280.5 (7.5)	281.0 (8.0)	281.5 (8.5)	282.0 (9.0)	282.5 (9.5)	283.0 (10.0)
313 (40)	68	66	63	61	58	56	53	51	49	47
308 (35)	65	63	60	57	55	52	49	47	44	42
303 (30)	62	59	56	53	50	47	44	41	39	36
289 (25)	57	54	51	47	44	41	38	34	31	28
293 (20)	52	48	44	40	36	32	29	25	21	18
288 (15)	44	39	34	30	25	21	16	12	8	4
283 (10)	32	27	21	16	10	5				
278 (5)	16	9	2							
273 (0)										
268 (-5)										
263 (-10)										

Air Volume Necessary for Engine Combustion

The minimum theoretical air volume necessary for the complete combustion of one kilogram of fuel is about 14.6 kg ≒ 12.5 m^3. In practice more air is needed. The ratio of auxiliary air volume to the theoretical minimum is called the excess air ratio.

In diesel engines, the excess air ratio is 1.5 - 2.0 at full load, i.e., the air volume needed is 1.5 - 2.0 times more than the theoretical minimum air volume.

The simple calculation to obtain the required air volume from the engine's total displacement is as follows.

Formula of Required Air Volume:

$$Q_1 = K_t \times V_s \times N \times C \times 10^{-3}$$

Q_1 :	Required Intake Air volume	m^3/min.
K_t :	Volumetric efficiency	
	• Naturally aspirated engine	0.85-0.9
	• Turbocharged engine	1.3
V_s :	Engine displacement	L
N :	Engine speed	rpm
C :	Constant, 4-cycle engine	1/2

EXAMPLE: Engine Model 4JH2-UTE

- Type: 4-cycle, vertical water-cooled diesel engine
- Aspiration: Turbocharged with intercooler
- Displacement: 1.817 L
- Maximum rating output: 74 kW (100.6 hp) / 3600 rpm

$$= \frac{1.3 \times 1.817 \times 3600 \times 0.5}{1000}$$

$$= 4.25 \ m^3/min$$

Basic Selection Criteria and Hull Data Collection Worksheet (Part 1)

Power Project:

_____ Re-power

_____ Original Equipment

Propeller Shaft Power Requirement:

_____ Horsepower

_____ Kilowatts

Range Requirement:

_____ Nautical Miles

_____ Statute Miles

Hull Type:

_____ Planing

_____ Displacement

_____ Semi-displacement

Hull Displacement:

_____ Vessel

_____ Equipment

_____ Engine

_____ Cargo

_____ Passengers

Performance Characteristics:

_____ Maximum Speed Requirement

_____ Acceleration (Snap-throttle, hole shots)

Engine Installation Arrangement:

_____ Single-screw

_____ Twin-screw

Inboard Drive Arrangement:

_____ Parallel

_____ Angle

_____ V-drive

Engine Series to Answer Requirements:

_____ GM series

_____ YM series

_____ JH series

_____ BY series

_____ LH series

_____ LP series

_____ LY series

_____ CX series

_____ SY series

Drive:

_____ Mercruiser Bravo Series

_____ Sail-Drive Series _____

_____ Other_____

Basic Selection Criteria and Hull Data Collection Worksheet (Part 2)

Number of Cylinders	Bore *X* Stroke	Power kW (hp)	Maximum rpm	Weight kg (lb)	Dimensions L x W x H

Hull Draft	Hull Beam	Hull Waterline Length	Maximum Hull Speed

Section 4

ENGINE MOUNTING

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ENGINE AND DRIVE CONFIGURATIONS

Engine alignment and mounting is a critical operation that requires a high level of accuracy and attention to detail. Engines need to be aligned and matched properly with shafts and marine gears while maintaining the appropriate positional relationship between the propeller and the vessel. The entire propulsion system (engine, shafts, marine gear and propeller) must engage the water in the most efficient way possible, answering the operator's performance requirements. For large vessels driven by high-power propulsion systems, a qualified naval architect must verify the application's structural integrity.

Engine mounting and configuration can be accomplished in one of two basic approaches:

- Inboard applications
- Sterndrive applications

Inboard applications generally have fixed propellers. In such systems, the propeller position is unchangeable relative to the vessel. Trim position can be adjusted on sterndrive applications, altering the relative position of the propeller to the vessel.

After the propeller position (inboard applications) or lower unit (sterndrive applications) is established relative to the vessel, the engine, shafts and marine gear must be positioned and mounted to drive the system in that position. When the system is properly installed, the propeller engaging the water is at the optimal position to answer the operator's requirements.

Each engine has inclination angle limits. Exceeding these limits causes engine cooling or lubrication problems. Refer to the engine specifications for appropriate data.

Engine and propeller selection are critical to successful installation and mounting. Engine selection precedes propeller selection. Refer to the *Propeller Selection* and *Engine Selection Guide* sections for more information.

Inboard Applications for Displacement and Semi-Displacement Hulls

Trim Tabs

Since inboard propulsion systems have propellers that are generally fixed, trim adjustments are not possible on such systems. Separate trim systems can be installed. A hydraulically controlled trim system contributes to vessel stability while underway **(Figure 4-1)**.

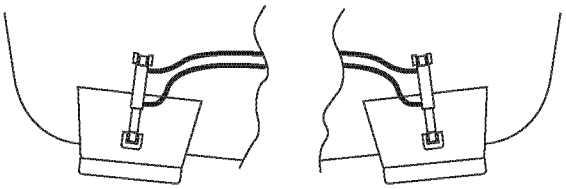

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Figure 4-1

Adjusting the trim tabs brings the vessel to level roll, compensating for changes in weight distribution as passengers move about the deck or cabin.

Marine Gear Systems

The marine gear is installed to transfer and control power from the crankshaft to the propeller driveshaft. Through a system of gears and reducers, engine power can be transferred to one of three positions:

- FORWARD
- AFT
- NEUTRAL

Type of Marine Gear

The basic types marine gear are the mechanical and the hydraulic mechanisms. These are operated by the remote control handle.

Mechanical

Mechanical gear systems are usually used with pleasure craft engines under 100 hp. They are usually used in sailboats because the propeller shaft has to be locked when cruising under sail to reduce propeller resistance. More force is needed to shift gears when using the mechanical gear.

Hydraulic

The hydraulic gear is usually used for boats with high output engines, especially powerboats. Hydraulic gear systems make shifting easier and are often used for dual station control systems.

Inboard Drive Configurations

The marriage between an inboard engine and a drive system can be accomplished in one of three possible configurations:

- Parallel Drive
- Angle Drive
- V-Drive

The drive configuration is selected based on the available engine room space. Each of these basic configurations are described as follows:

Parallel Drive

The output shaft of marine the gear is parallel to the crankshaft. **(Figure 4-2)**

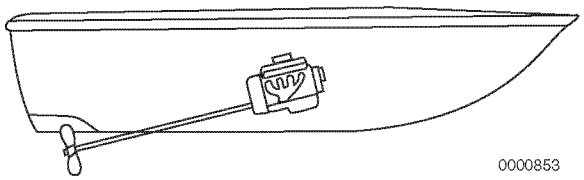

Figure 4-2

The engine is installed at a slant. This configuration offers the greatest engine and hull efficiency but often at the expense of living space in the cabin or cockpit.

Angle Drive

This configuration is sometimes called the down-angle drive system. The output shaft of the marine gear is inclined at 7-10° to the crankshaft **(Figure 4-3)**.

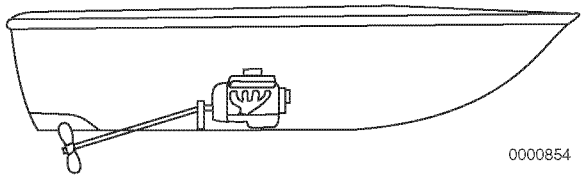

Figure 4-3

The gentle inclination of the engine / marine gear package reduces space requirements in the engine room. Some power loss is experienced because of the angle.

V-Drive

The output shaft of the marine gear forms a V-shape with the input shaft. The propeller shaft leads aft. The engine is installed with the driveshaft facing forward **(Figure 4-4)**.

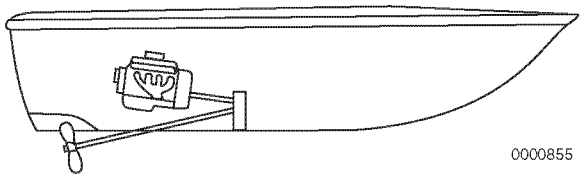

Figure 4-4

This configuration leaves vastly more room for living space in the cabin or cockpit. The disadvantage is the difficulty in selecting flexible engine mounts and the comparatively loss of horsepower.

Engine Configurations

Inboard or sterndrive engine configurations are installed in single- or multi-screw arrangements.

Single-Screw Configuration

The most basic configuration is the simple single engine application **(Figure 4-5)**.

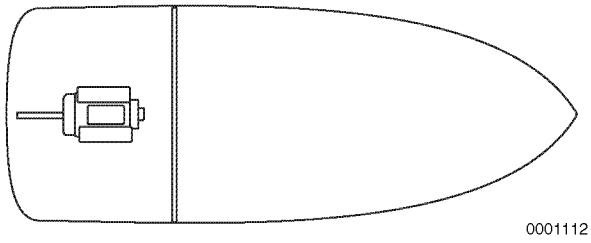

Figure 4-5

The ideal installation is one in which the propeller shaft is aligned with the vessel's center line. In small vessels, when right-hand propeller rotation is used, the helm is best situated on the starboard side. Propeller force tends to torque the vessel, sinking the port side of the vessel lower in the water. The helmsman's weight tends to counter that force. When left-hand propeller rotation is used, the helm is best situated on the port side.

Twin-Screw Configuration

Two-screw applications allow for greater power and maneuverability than single-screw applications. The power of both engines contribute to added thrust **(Figure 4-6)**. In congested harbors, marine gears can be shifted counter to one another. For example, if the port gear is shifted forward and starboard gear is shifted aft, the vessel can come to port far more sharply then a single-screw vessel.

Since the port propeller rotates counter to the starboard propeller, the propeller wash is equal on both sides with no measurable tracking.

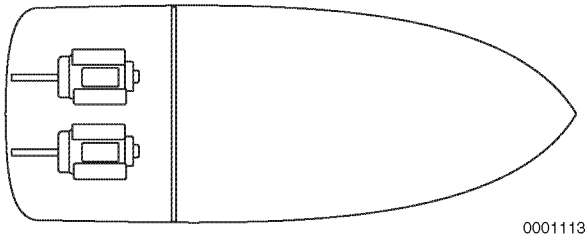

Figure 4-6

The ideal installation is one in which the propeller shafts are aligned with equal distance to the center line, maintaining perfect symmetry.

Staggered Twin-Screw

Staggered twin-screw applications allow for closer propeller shaft positions. With the propeller shafts closer together, a more stable cruise is achieved, especially at top speed **(Figure 4-7)**. Staggered configurations require more space in the engine room than standard arrangements.

Some power losses are associated with longer shafts and additional hardware. Balancing the weight distribution might require that other cargo rests in appropriate engine room locations to counterbalance engine weight.

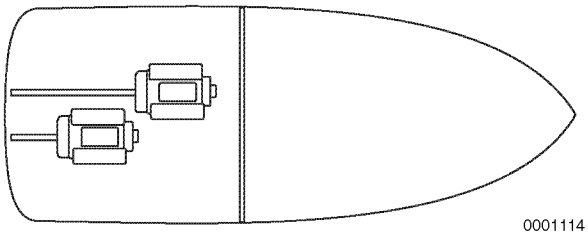

Figure 4-7

The ideal staggered installation is one in which the propeller shafts are aligned with equal distance to the center line and closer together than a traditional side-by-side system.

Triple-Screw Configuration

Three-engine applications allow for greater power and maneuverability than two-engine applications. The power of all engines contribute to added thrust **(Figure 4-8)**.

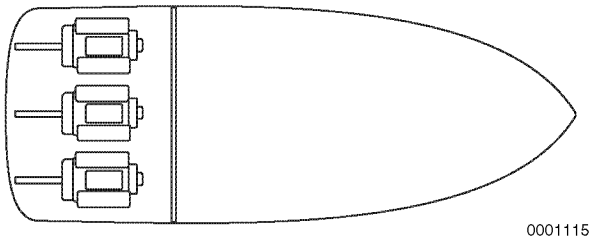

Figure 4-8

The ideal installation is one in which the port and starboard propeller shafts are aligned with equal distance to the center line. The center engine is aligned with the center line, maintaining perfect symmetry between all propellers.

Staggered Triple-Screw

Staggered triple-screw applications allow for closer propeller shaft positions than traditional side-by-side systems. With the propeller shafts closer together, a more stable cruise is achieved, especially at top speed **(Figure 4-9)**. Some power losses are associated with longer shafts and additional hardware.

The center propeller rotation is best when it rotates counter to the helm position.

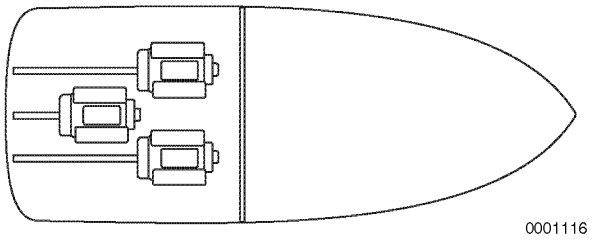

Figure 4-9

Sterndrive Applications for Planing Hulls

Engines matched with sterndrives are nearly always level-mounted with no forward-to-aft inclination when the vessel is at rest in the water. Multi-engine sterndrive applications are installed in standard or staggered configurations. The same principles of geometric symmetry and weight distribution that apply to inboard installations also apply to sterndrive applications.

ENGINE ROOM PREPARATION

⚠ DANGER

CRUSH HAZARD!

NEVER stand under hoisted engine. If the hoist mechanism fails, the engine will fall causing serious injury or death.

Failure to comply will result in death or serious injury.

0000008enMarine

⚠ WARNING

EXHAUST HAZARD!

- **NEVER operate the engine in an enclosed area such as a garage, tunnel, underground room, manhole or ship's hold without proper ventilation.**
- **NEVER block windows, vents, or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.**
- **Make sure that all connections are tightened to specifications after repair is made to the exhaust system.**
- **Failure to comply could result in death or serious injury.**

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The single most important area in the engine room is the space occupied by the engine. It is the engine position that is established first. All other equipment must be arranged around the engine in its ideal position. The angular position of the engine relative to the vessel is critical to overall performance.

Plan and install critical engine and support equipment before the actual engine installation. Special devices and fittings for the engine are often best installed before securing the engine onto the mounting system. The seacock cover location and related hull drilling are best addressed at this point in the process.

Preparing the engine room for engine installation is an exercise in space planning. The main considerations are:

- Seawater pick-up and cooling water requirements
- Engine angular position relative to the vessel (yaw, roll and pitch)
- Propeller shaft surface depth relative to the waterline
- Space requirements for engine systems in the engine room
- Serviceability (service space around the engine)
- Symmetry and weight distribution (affects roll)
- Engine room ventilation and combustion air requirements.

Hull at Rest in Water

IMPORTANT

Make sure the engine is installed on a level surface. If a Yanmar Marine Engine is installed at an angle that exceeds the specifications stated in the Yanmar Marine Installation manuals, engine oil may enter the combustion chamber causing excessive engine speed, white exhaust smoke and serious engine damage. This applies to engines that run continuously or those that run for short periods of time.

The propeller shaft angle varies depending upon the hull shape and the engine installation arrangement.

While the maximum allowable engine angle is up to 15°, the optimum propeller shaft angle for any application is 8° or less.

The maximum permissible engine angle is measured between the crankshaft center line and the waterline. The peak angle is the maximum engine angle that continues for under ten seconds during pitching (β & γ) or rolling (α) **(Figure 4-10, (4)).** These angles differ depending upon the engine model. The propeller shaft angle **(Figure 4-10, (1), (2))** relative to the waterline **(Figure 4-10, (3))** influences the engine inclination.

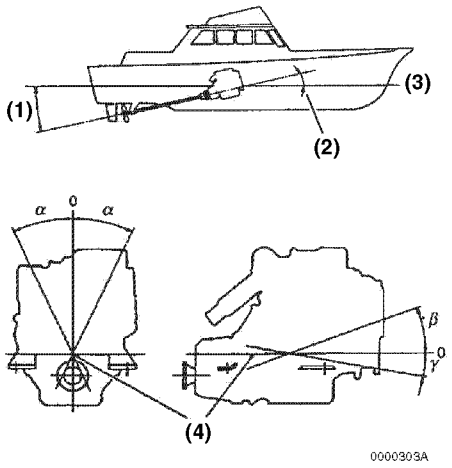


Figure 4-10

Engine inclination angles that exceed the engine's allowable limits can cause engine seizure, overheating or decreased propulsion efficiency due to hampered cooling and lubrication capacity.

Yaw Angle

Consider the propulsion system symmetry relative to the vessel's center line before engine installation and mounting. In both single-screw and multi-screw applications, driveshaft yaw angle relative to the center line must be held to a minimum.

The center line **(Figure 4-11, (1))** is defined as a theoretical line constructed parallel to the sea surface **(Figure 4-11, (3))** from the forward-most portion of the bow to a point on a vertical line constructed at the aft-most portion of the stern. **(Figure 4-11, (2)).** The center line is aligned with the vessel's true course line (ignoring current and wind influence) when underway.

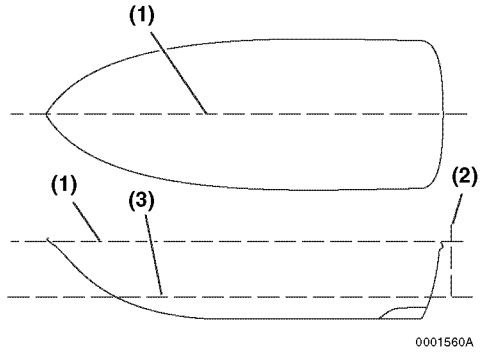


Figure 4-11

Driveshaft yaw angle is defined as the angle between two theoretical planes:

- **Propeller Shaft Plane** - A theoretical plane constructed perpendicular to the sea surface and parallel to the propeller shaft.
- **Vessel Center Plane** - A plane constructed perpendicular to the sea surface and parallel to the center line.

In a theoretically perfect single-screw installation, these two planes are one in the same. In practice, a margin of error is present for which correction is required **(Figure 4-12)**.

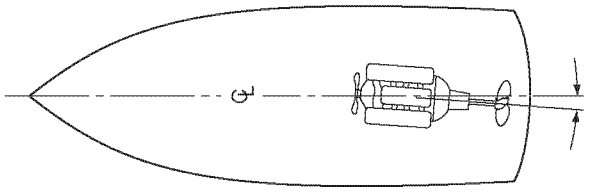


Figure 4-12

The stringers might not be parallel to the center line. They might not be level with the sea surface. If the stringer system is asymmetrical, alteration to the stringer system is needed. The angle between the stringer edge and a line constructed that is parallel to and adjacent to one end of that stringer, represents the stringer yaw angle.

Measuring Stringer Symmetry

1. Locate a point at the center line on the aft-most portion of the vessel.
2. Locate a point on the center line at least 5 cm (2.0 in.) forward of the forward-most portion of the stringers **(Figure 4-13, (1))**.

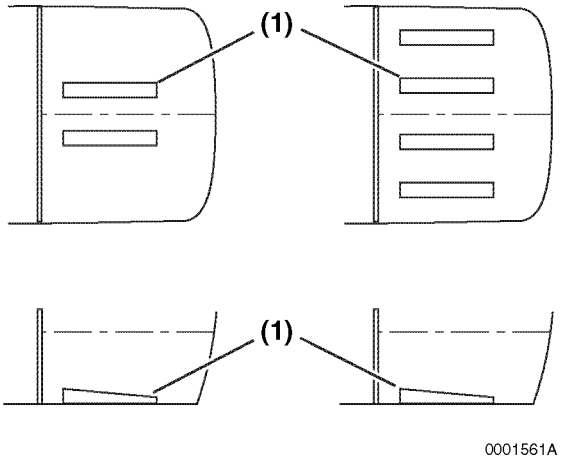


Figure 4-13

3. String a reference line between these two points.
4. Measure the distance between the center stringers to the aft center on both the port and starboard **(Figure 4-14, (1), (2))** sides.

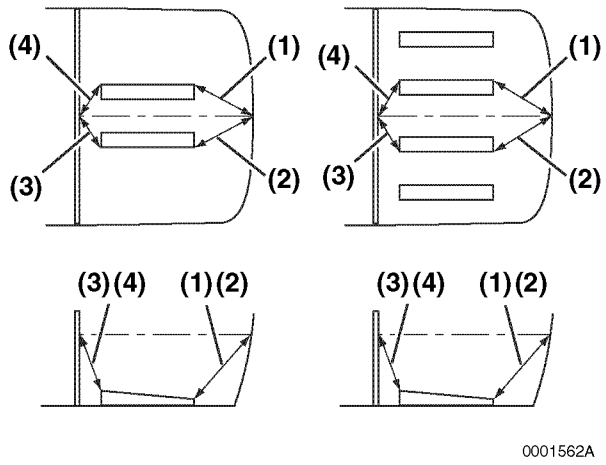


Figure 4-14

5. Measure the distance between the center stringers to the forward center on both the port and starboard **(Figure 4-14, (3), (4))** sides.

   If measurements from the port stringer to the center line are equal to the measurements from the starboard stringer to the center line, the stringers are properly centered. If not, modify as needed.

6. Identify the mounting hole locations for each stringer set based on installation drawings or templates.
7. Measure the cross-dimensions between the stringers in each stringer set **(Figure 4-15, (3)).** These measurements should be equal. If not, modify the stringer system as needed.

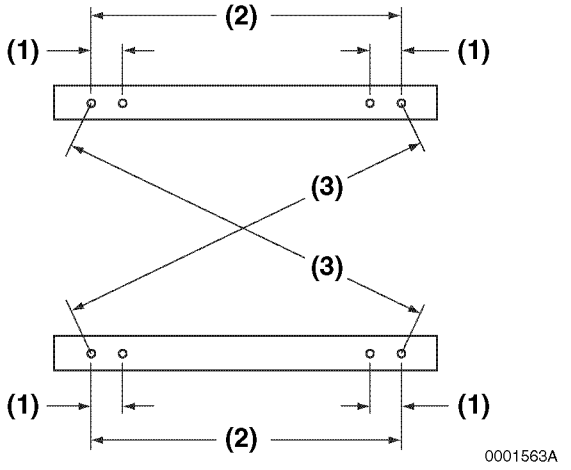


Figure 4-15

8. Measure the stringer length mounting hole dimensions center-to-center for each stringer set **(Figure 4-15, (2))**. These measurements should be equal. If not, modify the stringer system as needed.
9. Measure the individual mounting hole dimensions center-to-center for each stringer set **(Figure 4-15, (1))**. These measurements should be equal. If not, modify the stringer system as needed.
10. String a reference line **(Figure 4-16, (2))** between points as shown **(Figure 4-16, (1), (3))**.
11. Measure the angle between the line and the stringer.

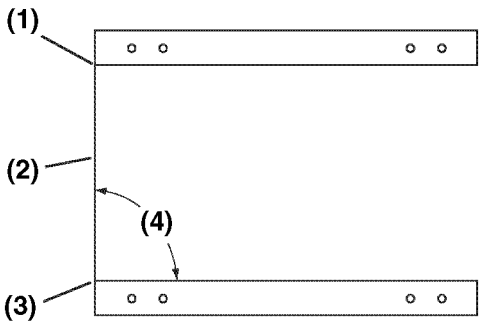


Figure 4-16

12. A measure of 90° **(Figure 4-16, (4))** indicates symmetry in the stringer system. Modify as needed.
13. Use a straightedge to ensure that the engine bed or stringer system is even, both forward-to-aft and port-to-starboard **(Figure 4-17, (1))**. Levels can be used if the vessel is moved, bringing the mounting system to a level position. The engine mounting hardware receives uneven stress if the engine mounting surfaces are uneven. This can loosen the mounting hardware during engine operation **(Figure 4-18)**.

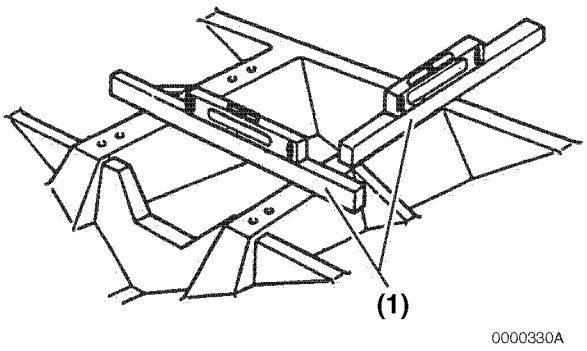
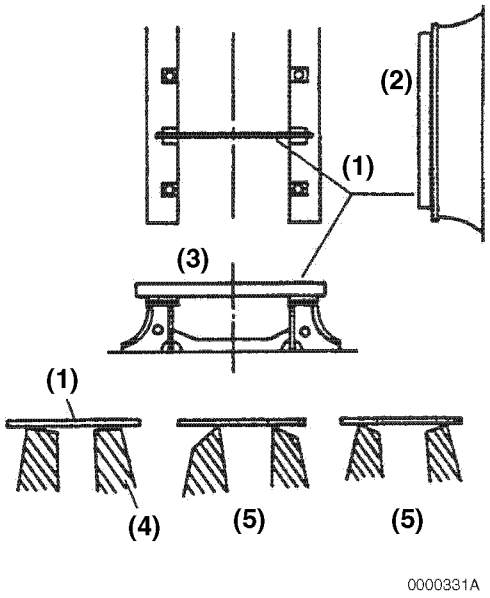


Figure 4-17



1 – Straightedge
2 – Stringer
3 – Port-to-Starboard Check
4 – Acceptable Mounting
5 – Unacceptable Mounting

Figure 4-18

Propeller Shaft Centering

The following steps represent the process by which the propeller shaft is properly centered and aligned. Drilling for shaft clearances is critical. Jigs can be designed for this purpose but the geometry is critical and must be verified before using such a jig.

1. Determine the forward-to-aft positions “o” and “y” of the propeller shaft center line as shown **(Figure 4-19)**.

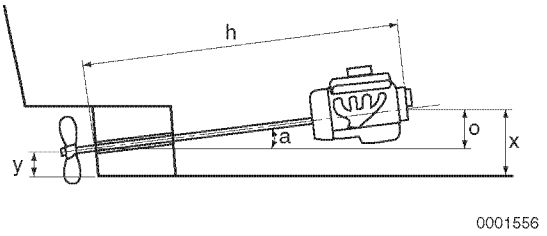


Figure 4-19

Apply the following formula when determining the forward-to-aft positions:

$$\sin \alpha = \frac{o}{h}$$

$$x = o + y$$

Where:

$\sin\alpha$ = Propeller shaft angle

o = Side opposite length

h = Hypotenuse length

y = Propeller height

x = Forward engine height

2. Drill a pilot hole smaller than the stern tube diameter **(Figure 4-20, (1)) (Figure 4-21, (7))**.

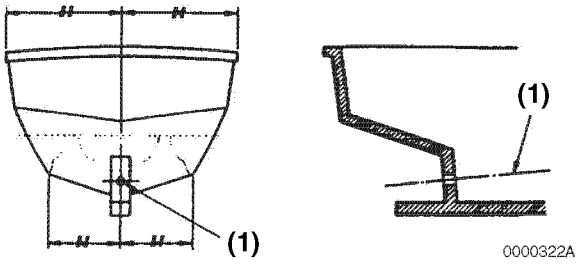


Figure 4-20

3. Pass a centering line **(Figure 4-21, (4))** through the pilot hole **(Figure 4-21, (3))** and fasten one end to the steering post **(Figure 4-21, (1))** and the other end to the forward engine room bulkhead. Observe the positional relationship between the stringer system **(Figure 4-21, (5))** and the centering line. Measurements must indicate symmetry. If not, modify as needed.

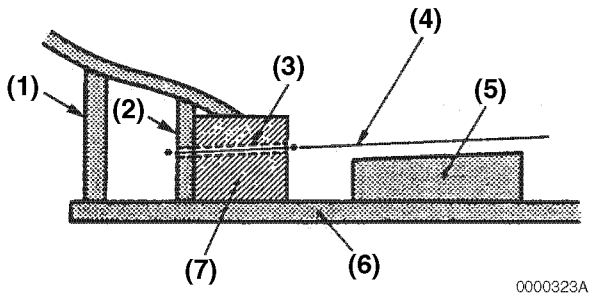


Figure 4-21

4. Measure the shaft angle between the hull floor and the centering line **(Figure 4-21, (6))** and ensure that the angle is consistent with the specification.
5. Ensure that the propeller dimensions are compatible with the space between the steering post **(Figure 4-21, (1))** and shaft penetration point **(Figure 4-21, (2))**.
6. Construct a parallel cross-frame jig and attach it to the aft bulkhead **(Figure 4-22)**.
7. Insert plate "A," **(Figure 4-22, (5))** which carries the centering line. Plate A should be moveable in all directions so that the line position can be corrected.
8. Fasten the line as illustrated in **(Figure 4-22, (2))** for easy removal. The hole in this plate permits pencil marking or inspection after line removal.

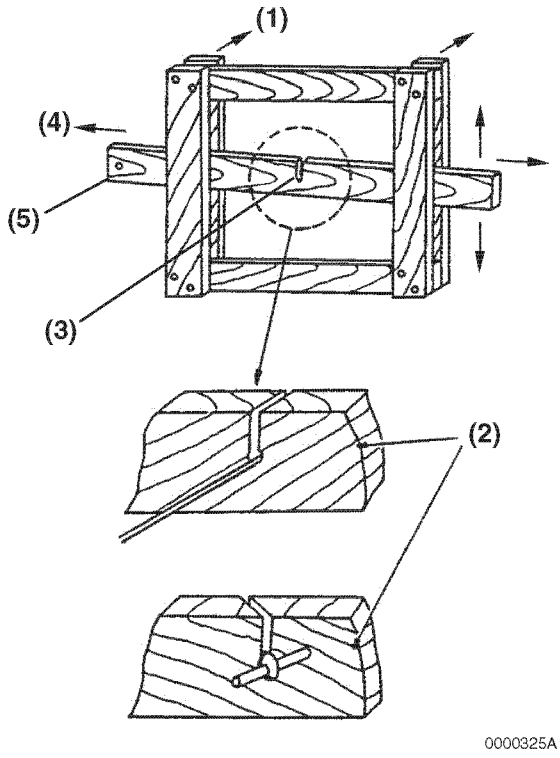
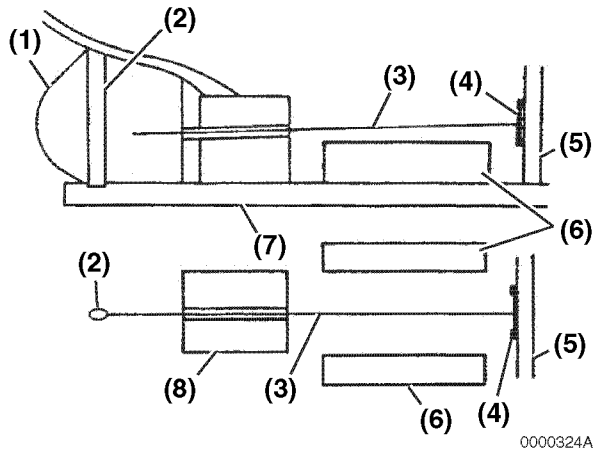


Figure 4-22

9. The jig **(Figure 4-22, (1))** allows for fine adjustments to the center **(Figure 4-22, (3))** line by moving the centering bar **(Figure 4-22, (4))**.
10. Refer to the installation drawings to determine a mounting arrangement on the stringer system that is consistent with the propeller shaft angle and engine inclination requirements. Build onto the stringer system as needed **(Figure 4-23)**.



1 – Rudder
2 – Steering Post
3 – Centering Line
4 – Jig
5 – Transom
6 – Stringer System
7 – Hull Floor
8 – Shaft Drilling

Figure 4-23

Final Drilling and Stern Tube Installation

1. Observe the centering line. This is the reference for the final drilling **(Figure 4-24, (1))**.

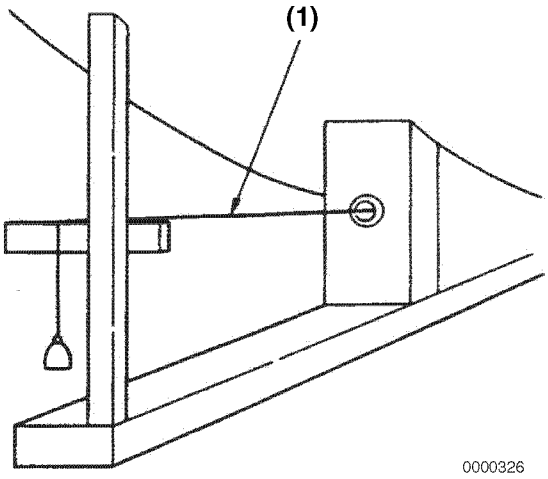
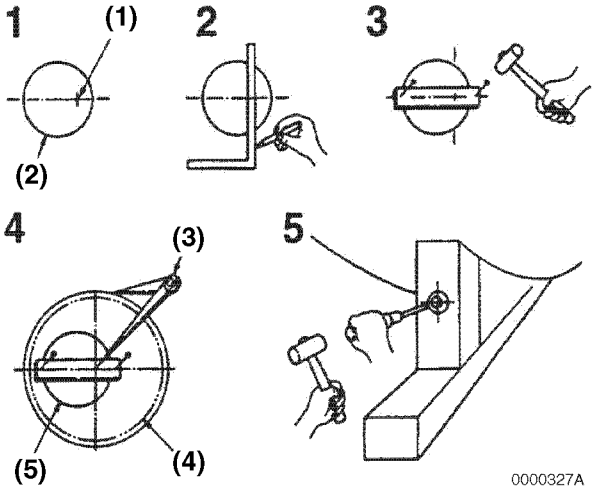


Figure 4-24

2. Using the centering line as a reference, scribe a precise cutting mark on each side of the stern box for the stern tube hole **(Figure 4-25)**.
3. Drill the final hole while maintaining the proper drill angle.



1 – Pilot Hole
2 – Squaring
3 – Temporary Drill Centering Block
4 – Scribing Mark
5 – Final Hole Location

Figure 4-25

Fitting to Stern Tube Tightening Surface

There are two types of stern tubes:

- Attached to the stern port
- Attached with bolts

1. When the stern tube attaches with bolts, apply sealing agent and secure with bolts **(Figure 4-26, (1))**.

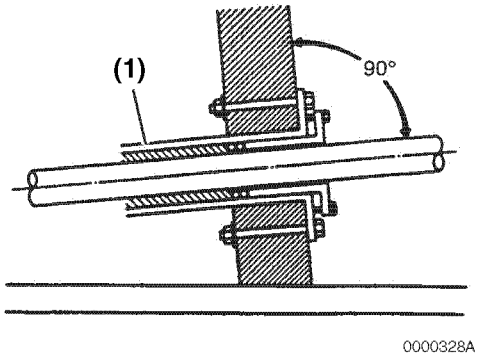


Figure 4-26

2. Apply an appropriate sealing agent on the stern tube exterior and press it into place.
3. Ensure that the stern tube is clear of sealing agent or any other foreign material.

Installing the Propeller Shaft

1. Apply an appropriate sealing agent, insert the propeller shaft and secure with bolts **(Figure 4-27)**. Avoid damaging the rubber or metal with the threaded parts.

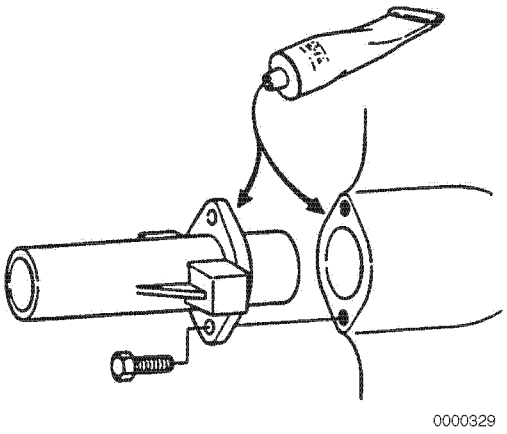


Figure 4-27

2. Temporarily attach the propeller shaft joint to the engine side and ensure that it rotates freely.

Engine Alignment

1. Attach the alignment device **(Figure 4-28, (2))** to the propeller shaft flange **(Figure 4-28, (1))** and prepare a centering line as shown.

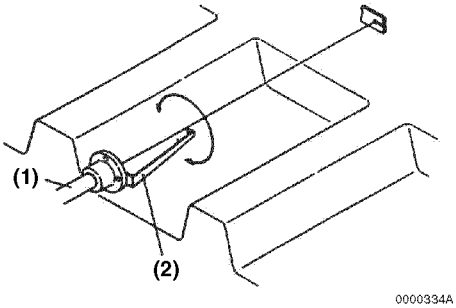


Figure 4-28

2. Slowly turn the propeller shaft. The alignment device **(Figure 4-29, (3))** rotates around the center line **(Figure 4-29, (2))**. With the center line centered in the shaft **(Figure 4-29, (1))** the amount of eccentricity is indicated by observing the end of the alignment tool relative to the center line.

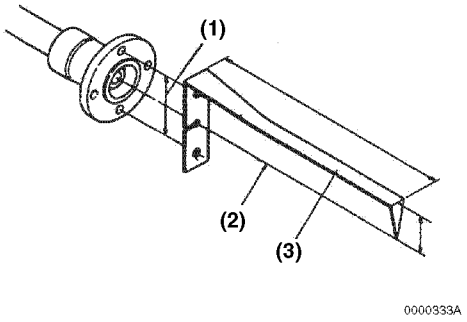


Figure 4-29

3. Adjust the centering line as needed.

Engine Mounts

1. Fabricate an accurate jig based on the installation drawings **(Figure 4-30)**. This jig must have indicating tabs that represent the true shaft location relative to the center line **(Figure 4-30, (2))**. The jig must also indicate space for the marine gear **(Figure 4-30, (1))**.
2. Temporarily attach the engine mounts to the jig.

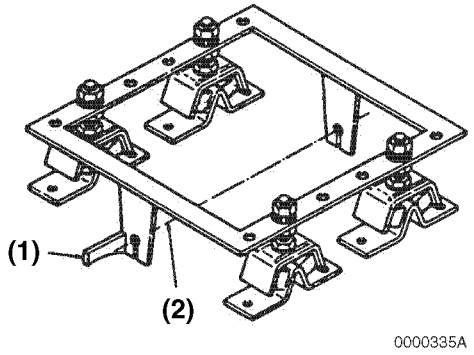
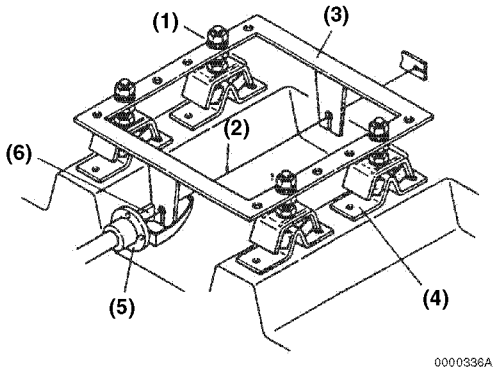


Figure 4-30

3. Place the jig on the stringer system over the centering line **(Figure 4-31)**.



1 – Adjusting Nuts
2 – Stringer
3 – Jig
4 – Engine Mounts
5 – Propeller Shaft Flange
6 – Center Line

Figure 4-31

4. Adjust the engine mounts to the approximate position that represents the propeller shaft. When fixing the flexible engine mount **(Figure 4-32, (1))** to the jig, ensure that dimension "H" is in the center of the adjusting range.

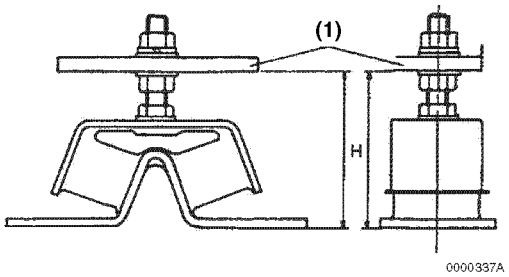


Figure 4-32

5. When the center of the propeller shaft is aligned, and the engine mounts properly positioned, clearly mark the engine mounting hole locations.
6. Label the mounts "*port forward*," "*port aft*," "*starboard forward*" and "*starboard aft*" accordingly.
7. Remove the jig.
8. Remove the flexible engine mounts from the jig.
9. With the mounting hole locations positively identified and marked, drill the holes.

Precise drilling reduces stresses across the mounts. If no jig is available, the holes can be drilled after the engine is set on the stringers. This method allows the engine with mounts attached to be used as a hole-marking template. If the holes are drilled before the engine is installed, the hole pattern must be accurate to within 1.5 mm (0.06 in.) on all the dimensions.

HOISTING ENGINE INTO PLACE

DANGER

CRUSH HAZARD!

NEVER stand under hoisted engine. If the hoist mechanism fails, the engine will fall causing serious injury or death.

Failure to comply will result in death or serious injury.

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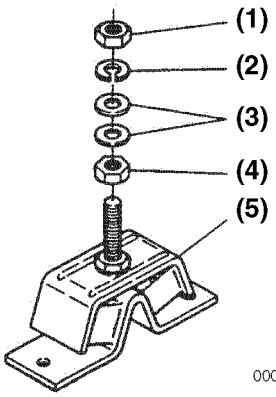
Do not allow the engine to fully rest on the mounts until the marine gear and propeller shaft are properly aligned.

1. Raise the engine to a working height and attach the mounts **(Figure 4-33)** and any other equipment as required.



1 – Top Adjusting Nut (Over Engine Mounting Flange)
2 – Top Adjusting Washer (Over Engine Mounting Flange)
3 – Top Flange Washers (Engine Mounting Flange Location)
4 – Lower Adjusting Washer (Under Engine Mounting Flange)
5 – Lower Adjusting Nut (Under Engine Mounting Flange)

Figure 4-33

2. Lower the engine into place, bringing the four mount bases to the correct position on the stringers.

CAUTION

NEVER move the adjustment nuts without using a hoist to take the pressure off the engine mount. Failure to comply may cause damage to the stud and nut threads.

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3. Insert the bolts into the stringers and tighten finger-tight. Align the engine and marine gear with the propeller shaft to specification and begin to transfer the weight of the engine from the hoist to the mounts by using the adjusting nuts on all the mounts.

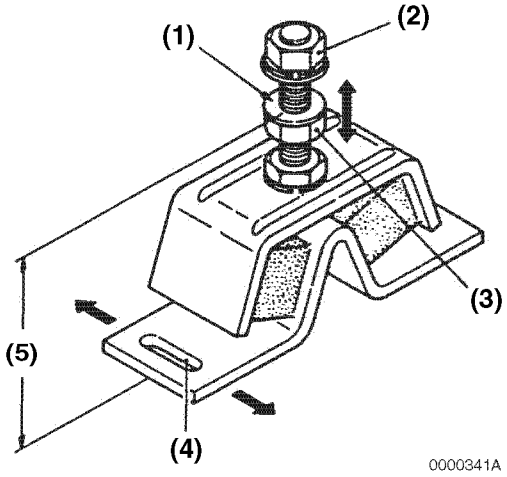
NEVER move the adjusting nuts without lift assistance from the hoist until the engine weight is nearly evenly distributed. Failure to support the engine could result in damage to the stud and nut threads. Once the weight is evenly distributed, the hoist can be removed.

The mounts are fully adjustable to accommodate engine alignment and weight distribution. Any mounting adjustments can influence weight distribution. Ensure uniform weight distribution between mounts by adjusting the mounts to bring the engine's center of gravity as close as possible to the center of the mounting pattern. This equalizes the engine and marine gear weight that each isolator mount bears. In some applications, the forward-to-aft loads cannot be completely equalized. The port-to-starboard load must always be equalized.

On pin-style mounts, the pin serves as a load indicator. The mount is correctly loaded when the pin is at least 3.0 mm (.012 in.) from the edge of the hole in the cast housing. If the pin is touching the top of the hole, the mount is under-loaded and cannot isolate vibration efficiently. If the pin is at the bottom, the mount is overloaded and vibration dampening is ineffective.

On cushioned snubber-style mounts, the bottom rubber snubber, located between the cast housing and the stringer, serves as a load indicator. When the isolator is properly loaded the rubber snubber should not be touching the housing or the stringer, with approximately 3.0 mm (.012 in.) gaps above and below the snubber. If the snubber is touching the housing, the mount is under-loaded and does not isolate properly. If the snubber is touching the stringer, the mount is overloaded.

4. To apply a load to a mount, turn the adjusting nut upward, against the engine, lifting the engine at that corner and compressing the snubber. To reduce the load to a mount, turn the adjusting nut downward, away from the engine, lowering the engine at that corner and decompressing the snubber. Adjust the mount loads until the port and starboard forward mounts have equal snubber gaps and the port and starboard aft mounts have equal, or near equal snubber gaps **(Figure 4-34)**.



1 – Engine Mounting Flange Location
2 – Top Adjusting Nut
3 – Lower Adjusting Nut
4 – Port-to-Starboard Adjusting Slot
5 – Vertical Adjustment

Figure 4-34

5. Adjust the base flanges in or out as needed and tighten the stringer flange bolts to specification.

Stringer Bolts	Torque
M10	46.10 - 52.00 N·m (34 - 38.34 ft-lb)
M12	83.3 - 93.17 N·m (61.49 - 68.72 ft-lb)
M14	117.68 - 127.49 N·m (86.80 - 64.03 ft-lb)

Adjusting the mount snubber gaps could change the shaft flange alignment. Check alignment and repeat the process as needed to ensure that the isolators are properly loaded and the engine is aligned with the shaft. If major adjustments are needed to achieve the proper loading and alignment, shims or stringer modification could be required to center the isolator studs to the engine support bracket. When the nuts are tightened, ensure that the top nut is equal to or less than 2.0 mm (0.08 in.) from the flattened region of the stud. If the nut is too high on the stud, shims must be added under the mount.

6. Tighten the lower and the upper nuts to specification. Hold the adjusting nut and tighten the jam nut against the adjusting nut. Hold the flats on the stud and tighten the top nut **(Figure 4-35)**.

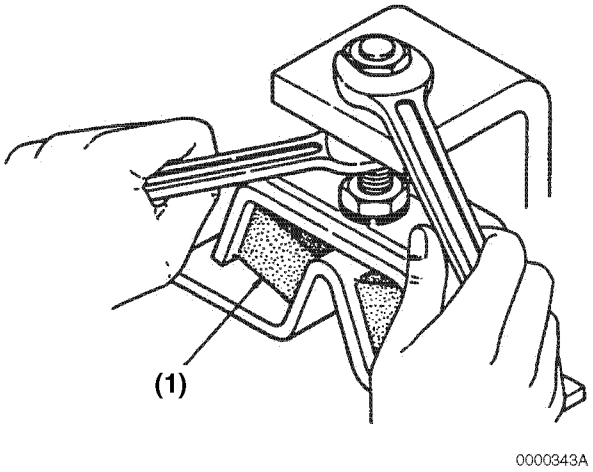


Figure 4-35

It is normal to see the rubber portion of the mount bulge with adjustments **(Figure 4-35, (1))**.

	Adjusting Nut, Jam Nut	Top Nut
0.75 in. diameter stud	129 N·m (95 ft-lb)	195 N·m (144 ft-lb)
1.0 in. diameter stud	181 N·m (134 ft-lb)	285 N·m (210 ft-lb)

Mounts will settle slightly three to five days after installation. Five days after installation, recheck the alignment between the marine gear and the shaft. Five days after installation, recheck the snubber spacing. Repeat mount adjustments as needed.

MARINE GEAR ALIGNMENT

Before connecting the marine gear driveshaft to the propeller shaft, ensure that the flange surface of both parts are parallel to each other and that their centers are aligned. Adjust the centering of the engine as follows:

1. Attach the shaft to the marine gear finger-tight.
2. With the propeller shaft loose, pull it up as far as it can travel. Then push it as far down as it can travel. Next, move the shaft to the mid-point between these two extremes and tighten the bolts enough to hold the shaft in that position.
3. Insert a feeler gauge between the propeller shaft coupling halves at four equally-spaced points around the circumference **(Figure 4-36)**. Adjust as needed and torque to specification.

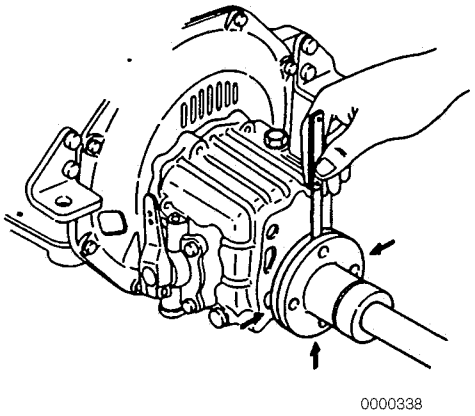


Figure 4-36

4. Using a dial gauge **(Figure 4-37, (2))** turn the propeller shaft **(Figure 4-37, (4))** and measure the outside run-out. Adjust to minimize run-out as needed **(Figure 4-38)**.

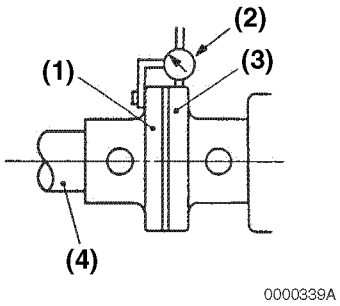
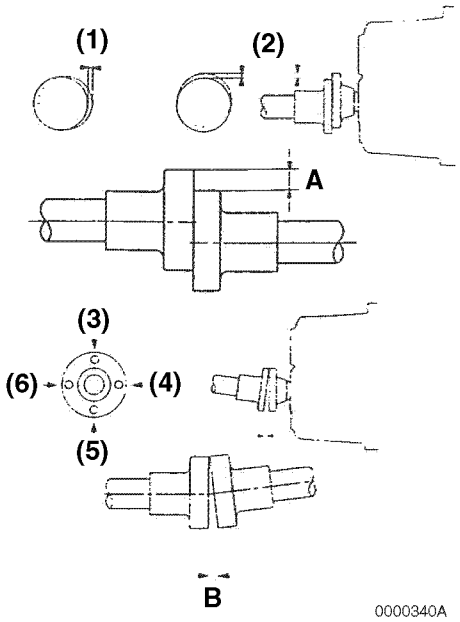


Figure 4-37



1 – Vertical Error Eccentricity (A)
2 – Horizontal Error Eccentricity (A)
3 – First Bolt Axial Alignment (B)
4 – Second Bolt Axial Alignment (B)
5 – Third Bolt Axial Alignment (B)
6 – Fourth Bolt Axial Alignment (B)

Figure 4-38

Measuring Point	Limit
Coupling alignment, A	0.1 - 0.3 mm (0.004 - 0.012 in.)
Coupling face run-out, B	0.0 - 0.2 mm (0.0 - 0.008 in.)

5. After tightening the bolts, ensure that the shaft coupling face has not slipped. If shaft coupling has slipped, readjust as needed.
6. Recheck shaft centering after launching once the sealing agent is completely cured. If there is any change in the centering, readjust.
7. Tighten the propeller shaft coupling flange with the output flange of the marine gear.

Bolt Size	Tightening Torque
M10	4.7 - 5.3 kgf-m 46.1 - 52.0 N·m (34.0 - 38.3 ft-lb)
M12	8.5 - 9.5 kg-m 83.4 - 93.2 N·m (61.5 - 68.7 ft-lb)
M14	12.0 - 13.0 kg-m 117.7 - 127.5 N·m (86.8 - 94.0 ft-lb)

ENGINE MOUNTS AND HULL VIBRATION

CAUTION

Excessive vibration may cause damage to the engine, marine gear, hull and on-board equipment. In addition, it causes noticeable passenger and crew discomfort. Carefully select engine mounts and propellers when you design Yanmar marine engine applications.

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Vibration produces useless kinetic energy that is expended in areas that do not contribute to vessel propulsion. Mechanical noise and performance deficits are unwanted by-products of excessive vibration.

Damage to the engine, marine gear, hull and on-board equipment all result from excessive vibration. It also causes noticeable passenger and crew discomfort. Minimizing vibration results is smoother, quieter cruising while reducing or eliminating the discomfort and damage it causes.

Accelerometers are used to measure the frequency (Hz) and force (G) associated with vibration. Sound level meters (SLV) are used to measure the frequency (Hz) and amplitude in decibels (dB) of audible noise generated by energy as it radiates from vibrating equipment through the air. These instruments are sometimes used for sea trials.

The two factors that most affect vibration are:

- Engine mounts
- Propeller selection

The flexible engine mounts that are shipped with some Yanmar engines reduce vibration by as much as 50%. Yanmar flexible engine mounts are designed to reduce vibration through the engine's operating range. At the resonance point the amplitude is at its greatest. This peak vibration is rolling, centered around the propeller shaft **(Figure 4-39, (1))**.

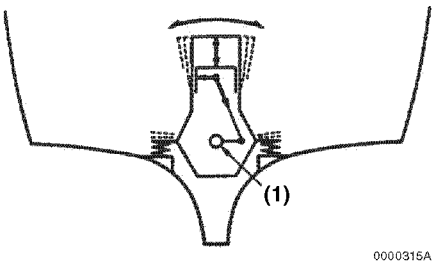
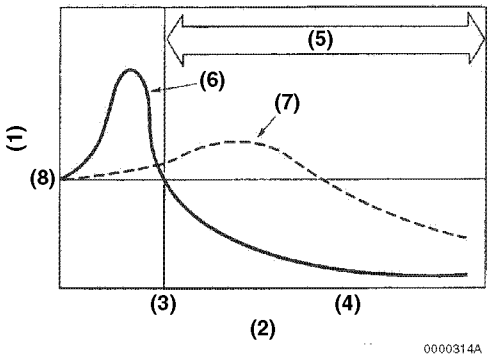


Figure 4-39

Vibration severity changes as a function of hull speed. **Figure 4-40** illustrates the relationship between marine gear and engine vibration at varying speeds. Lowering the spring constant lowers the resonance point.



1 – Anti-Vibration Characteristics
2 – Vibration Transition Rate
3 – Idling with Marine Gear in Neutral
4 – Increasing Vessel Speed
5 – Operating Range
6 – Flexible Engine Mounts
7 – Rigid Engine Mounts

Figure 4-40

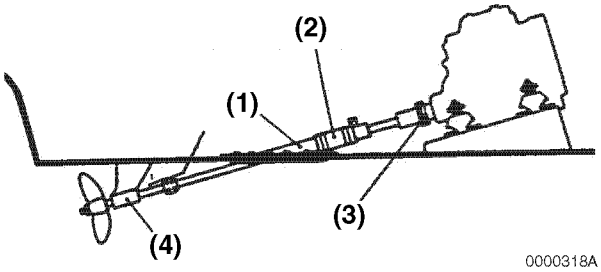
The upper part of the engine vibrates to a larger degree than the propeller. For information on propeller vibration, refer to the *Propeller Selection* section of this manual.

SHAFT CONSIDERATIONS WITH FLEXIBLE ENGINE MOUNTS

Engines mounted on flexible mounts have a measure of mobility relative to the hull. At rest, a non-operating engine could exhibit a measure of static distortion.

Engines that are installed with flexible engine mounting systems must be equipped with a flexible coupling or a flexible stern **(Figure 4-41)**.

Note: Even if the flexible coupling and flexible stem tube are used, they will not be effective if the centering alignment between the marine gear output shaft flange and the propeller shaft is too large.



1 – Flexible Shaft Tube
2 – Flexible Propeller Shaft Coupling
3 – Flexible Marine Gear Shaft Coupling
4 – Flexible Propeller Shaft

Figure 4-41

The following illustrations represent examples of flexible couplings **(Figure 4-42)** and **(Figure 4-43)**.

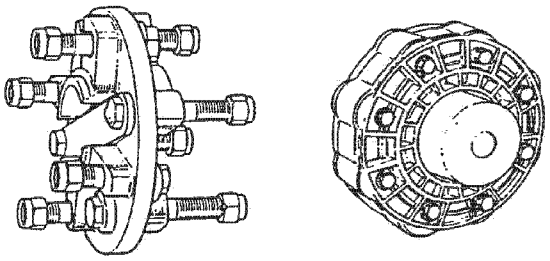


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Figure 4-42

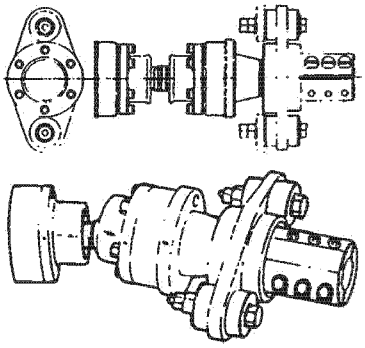

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Figure 4-43

Section 5

PROPELLER SELECTION

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GENERAL

The process of matching marine engines to appropriate propellers is a complex one that requires a wide range of special considerations. An analysis of the engine, the hull, the vessel purpose and the required vessel performance characteristics are all integral components of the propeller selection process. It is a process that is best left to engineers and technicians who are specifically trained in this highly specialized area of marine propulsion technology.

Propeller manufacturers are interested in ensuring that the best possible match between the vessel's engine and its propeller is achieved. Seek advice from the manufacturer's application specialists in selecting the best possible propeller type and size.

The degree to which the propulsion system answers the operator's requirements for a particular vessel is the extent to which the project is successful. When the appropriate propeller is selected, the result is a propulsion system that is ideally matched to a vessel. When the process completely meets all of the operator's requirements, the process is successful.

This material is published to aid qualified boat builders, engineers and technicians in selecting the best possible propellers for a wide range of applications. Attention is given to propeller types, performance issues, shaft considerations, multi-engine applications, power rating standards and sea trials. Rarely is the best possible match identified with engineering data alone. Generally, extensive experimentation during sea trials is invaluable in identifying the absolute, best possible propeller.

VIBRATION

CAUTION

Excessive vibration may cause damage to the engine, marine gear, hull and on-board equipment. In addition, it causes noticeable passenger and crew discomfort. Carefully select engine mounts and propellers when you design Yanmar marine engine applications.

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The effects of vibration and noise are felt in poorly matched propulsion systems through the human senses. Propeller vibration is a rapid propulsion component movement caused chiefly by imbalances in propellers, shafts or engines. This vibration produces useless kinetic energy that is expended in areas that do not contribute to vessel propulsion. Mechanical noise, rattling and lateral vessel tracking are all unwanted by-products of excessive vibration.

Damage to the engine, marine gear, hull and on-board equipment all result from excessive vibration. It also causes noticeable passenger and crew discomfort. Minimizing vibration results in smoother, quieter cruising while reducing or eliminating the discomfort and damage it causes.

Accelerometers are used to measure the frequency (Hz) and force (G) associated with vibration. Sound level meters (SLV) are used to measure the frequency (Hz) and amplitude in decibels (dB) of audible noise generated by energy as it radiates from vibrating equipment through the air. These instruments are sometimes used during sea trials which help confirm that the proper propeller was selected for the application.

PROPELLER STYLES

Propellers are manufactured in a variety of styles, addressing different power and speed requirements. Propellers are available in two, three, four and five blade configurations. Propeller style is determined by the vessel performance requirements.

Two-Blade Style

A two-bladed propeller is practical for slow speeds as in light trawler or sailboat applications **(Figure 5-1)**.

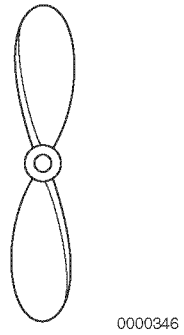

Figure 5-1

Multi-Purpose Style

The most common propeller style is a three-bladed multi-purpose type. It provides adequate performance over the widest range of power and speed applications **(Figure 5-2)**.

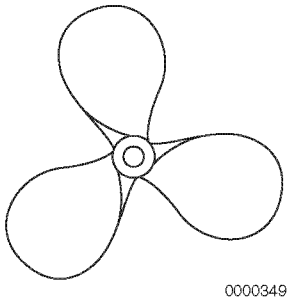

Figure 5-2

Finished sharp sections tend to maximize performance for faster, planing hull applications. More rounded, sweeping sections tend to provide greater power at slower speeds.

Cleaver Style

High performance vessels often use cleaver style propellers **(Figure 5-3)**. They are ideal for competitive racing and sailboat applications. With outstanding acceleration, speed and power characteristics, these propellers perform well over a wide range of rpm settings, particularly in high end applications with step-up marine gears. The blades are typically heavily skewed and raked aft. Cleaver propellers have a large blade area that provides greater thrust than its radiational style counterparts.

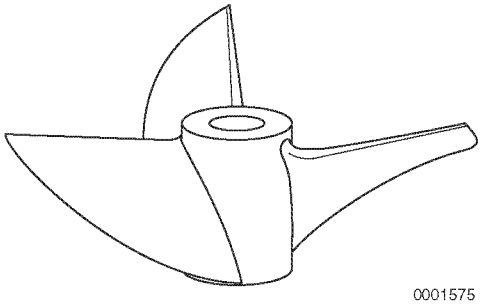

Figure 5-3

Surface-Piercing Style

Surface-piercing propellers are designed to operate with each blade out of the water half of each revolution while underway **(Figure 5-4)**. This generally requires that the propeller shaft be extended some distance aft of the transom. When the vessel is underway, the effective waterline passes through the propeller's center at the hub.

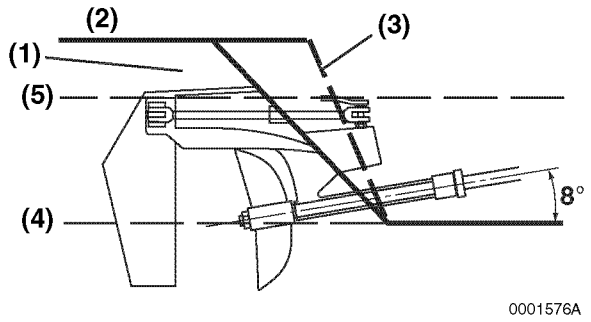

Figure 5-4

Fixed-shaft surface-piercing arrangements require a rudder, while articulated arrangements can actually change the propeller attitude achieving steering and trim settings **(Figure 5-5)**. Articulated drive systems for surface-piercing propellers do not need rudders.

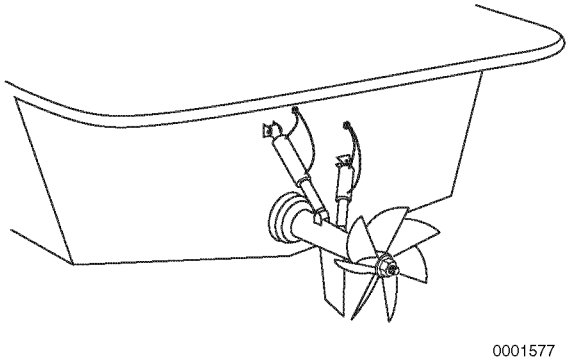

Figure 5-5

While surface-piercing systems are heavily ventilated, they virtually eliminate cavitation. This drive arrangement produces the least amount of drag and is seen most often in high-performance applications. Because the propeller is separated from the vessel by some distance, there is practically no limitation to the propeller diameter, other than horsepower. The vessel draft is not limited by the propeller to the same extent that traditional inboard or stern drives limit draft.

Adjustable Pitch Style

Adjustable pitch propellers are chiefly used in motor sailers and other relatively slow craft. The greatest advantage rests in its ability to adjust the pitch at different running speeds while underway. The propeller pitch can be adjusted to the ideal setting in a variety of weather conditions and vessel speeds. These systems require hollow propeller shafts for linkages.

Folding Style

Sailboats are also power boats. They have auxiliary power for use in harbors or when the vessel is becalmed. The engine power and speed requirements are relatively small in sail applications. When a vessel is operating under sail, its propeller is a liability. A propeller that is not generating thrust introduces unwanted drag, slowing the vessel.

A folding propeller provides propulsion under power, while folding under the water pressure that results when the vessel is operating under sail **(Figure 5-6)**.

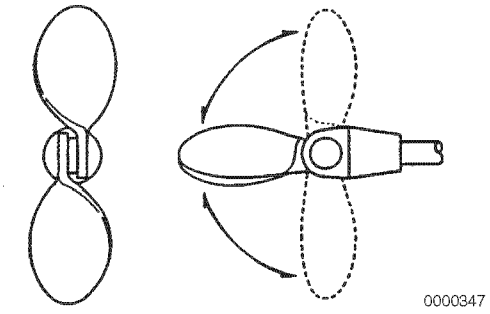

Figure 5-6

As the vessel is driven through the water by sail power, the water pressure folds the propeller blades aft, reducing unnecessary drag. The net result is increased speed under sail.

Folding propellers have three main liabilities:

- Folding propellers are less efficient than fixed propellers.
- Folding propellers have moving parts that are more likely to fail than fixed propellers with no moving parts.
- Folding propellers are less effective in slowing the forward momentum of vessels than fixed propellers. These propellers are sometimes unreliable or ineffective during reverse thrust demand. As a result, safe maneuvering speed in congested harbors and waterways is reduced compared to fixed propeller installations.

PROPELLER PERFORMANCE AND DIMENSION CONSIDERATIONS

The performance characteristics of a propulsion system are influenced by three factors:

- Hull size and shape
- Engine power curves
- Propeller size and type

Performance characteristics are observed in the areas of speed, power and maneuverability. Propeller selection is the process of matching hull and engine characteristics to the operator's performance requirements with the appropriate propeller style, size and material.

Speed

When absolute top speed is achieved, it is at the expense of power at lower speeds and acceleration. The absolute top speed is limited by the hull type and displacement combined with engine power. If these components are treated as constants, propeller variables can be manipulated to achieve top speed.

Power

When absolute peak power is achieved at slower speeds, it is at the expense of absolute top speed. The absolute peak power is limited by engine power. If engine power is treated as a constant, propeller variables can be manipulated to achieve peak power.

Pitch

Pitch determines the distance that a vessel travels for each revolution of the propeller. Propellers are manufactured in constant pitch or progressive pitch configurations. Constant pitch configurations offer a uniform effective pitch over the full range of engine rpm. Progressive (sometimes called variable pitch) configurations have different pitch characteristics at varying engine rpm. In both cases, high pitch propellers require greater power to operate at higher speeds.

Rake

Rake is the angle (negative or positive) of the blades relative to the shaft. Positive rake propellers are generally high performance propellers that are slanted aft **(Figure 5-7)**. They provide added stern lift at takeoff and greater bow lift at high speeds. Positive raked propellers also reduce ventilation.

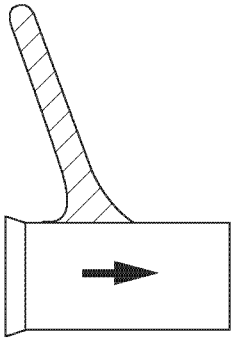

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Figure 5-7

Negative rake propellers are propellers that are slanted forward **(Figure 5-8)**. They provide less stern lift at takeoff and less bow lift at high speeds. The performance deficits are offset by increased efficiency and fuel economy.

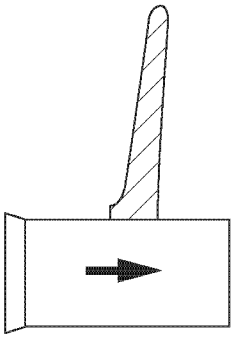

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Figure 5-8

If the rake is neither negative or positive, it is zero degree **(Figure 5-9)**. This design represents a compromise between negative and positive rake propellers.

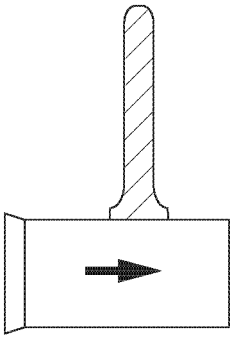

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Figure 5-9

Any rake angle can have a parabolic shape, increasing area and cup **(Figure 5-10)**.

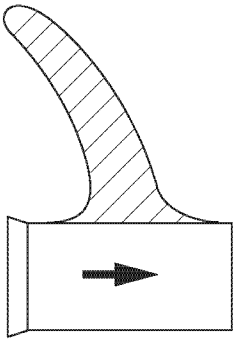

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Figure 5-10

Diameter

If an imaginary circle were scribed around the propeller tips, the diameter of that circle would be the propeller's diameter. Larger diameter propellers require greater power to operate at peak performance.

Area

Increasing the aft-blade portion surface area improves propulsion efficiency. Increasing the number of blades increases total area, resulting in greater efficiency over propellers with fewer blades. Generally, four-blade propellers are more efficient than three-blade ones. An increase in the area and number of blades provides improved dynamic stability over a wide range of speeds.

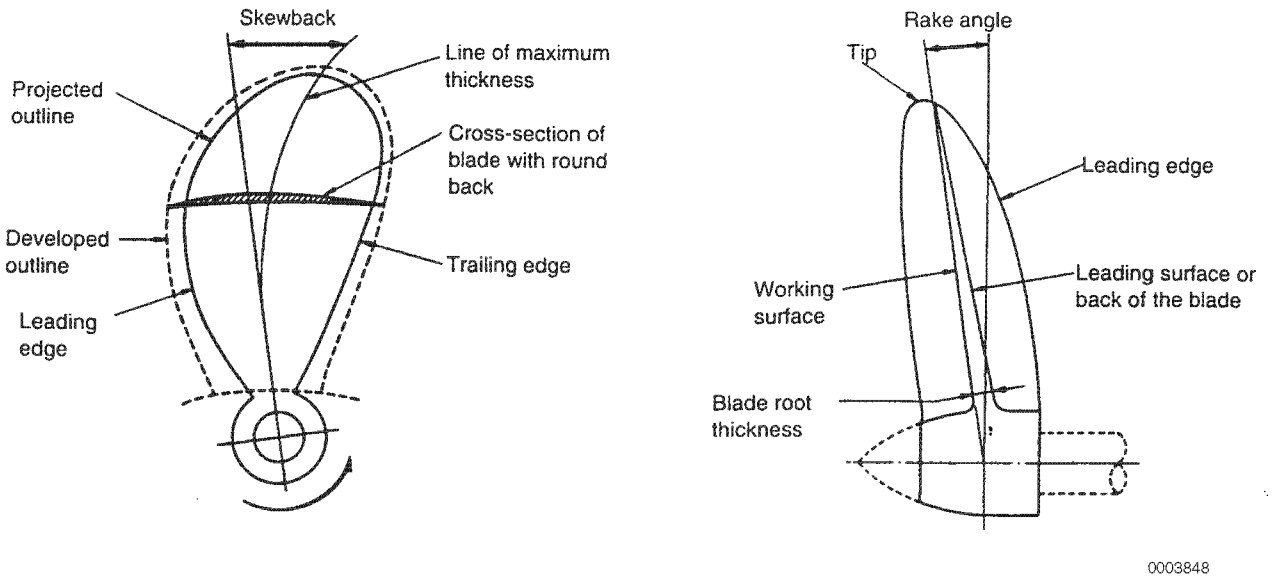


Figure 5-11

PROPELLER SHAFT CONSIDERATIONS

Diameter

This section describes Yanmar recommended propeller shaft diameter calculations. Three methods are described.

JCI Method

The following method is equivalent to the Japan Craft Inspection Organization (JCI) rule.

Formula

$$d = 154 \times \frac{1}{\sqrt[3]{T}} \times \sqrt[3]{\frac{(1+Y)H}{R}}$$

Where:

- d : Propeller shaft diameter (mm)
- T : Allowable torsional stress,
  5.0 kgf/mm = Stainless steel, JIS SUS304
  10.5 kgf/mm = Stainless steel, JIS SUS630
- Y : Torque fluctuation factor
  (4-cycle diesel engine)
- H : Max. engine output hp
- R : Propeller shaft revolutions rpm

No. of Cylinder	Factor
1	0.6
2	0.4
3	0.3
4	0.2
Over 6	0.1

Note: The above formula assumes the use of JIS SUS304 and SUS630 stainless steel for the propeller shaft and the shaft bearing being installed within 1.2 m from propeller shaft.

Example:

Engine: 4 cylinder, 4-cycle diesel engine
Maximum output: 40 hp / 3600 rpm
Reduction ratio: 2.5
Material of propeller shaft: SUS304 and SUS630

Propeller shaft rpm:

$$R = \frac{3600 \text{ rpm(Max. Eng. speed)}}{2.5 \text{ (Reduction ratio)}} = 1440 \text{ rpm}$$

1. With stainless steel, SUS304

$$d = 154 \times \frac{1}{\sqrt[3]{5}} \times \sqrt[3]{\frac{(1+0.2)\times 40}{1440}}$$

$$= 154 \times 0.58 \times 0.32$$

$$= 28.58 \text{ mm diameter}$$

2. With stainless steel, SUS630

$$d = 154 \times \frac{1}{\sqrt[3]{10.5}} \times \sqrt[3]{\frac{(1+0.2)\times 40}{1440}}$$

$$= 154 \times 0.46 \times 0.32$$

$$= 22.67 \text{ mm diameter}$$

One-Fourteenth Method[1]

The oldest and simplest rule for determining propeller shaft diameter is simply that it should be one-fourteenth of the propeller diameter. In spite of its simplicity, this rule works surprisingly well. A 914 mm (36 in.) diameter propeller would require a 65.3 mm (2.57 in.) diameter shaft, by this method.

The one-fourteenth rule, however, does not take into account many of the variables in selecting the best propeller shaft. It does not reflect differences between shaft materials - tobin bronze has roughly 60 percent of the strength of Monel 400, for instance. It also does not take into account that many possible combinations of shaft horsepower and rpm of propeller shaft will dramatically affect torque, though it makes some allowance for this by assuming that the propeller is correctly sized to absorb the engine's power.

[1] Dave Gerr, *Propeller Handbook* (Maine, International Marine, 2001).

In spite of its shortcomings, the one-fourteenth rule should be considered in making a shaft selection, if only for the fact that if a selected shaft diameter varies very widely from the rule, the propeller hub may require special machining.

Data Chart Method

Tables 5-1, 5-2, 5-3 and 5-4 give the diameter for solid tobin bronze propeller shafts at varying shaft horsepower and propeller shaft rpm. For shafts of Monel 400, the diameter should be reduced by 20 percent. The curves on the chart are derived through the following formula:

Shaft Diameter Formula

$$D_s = \sqrt[3]{\frac{321,000 \times SHP \times SF}{St \times rpm}}$$

Where:

D_s = Shaft diameter, in inches
SHP = Shaft horsepower
SF = Safety factor (3 for yachts and light commercial craft, 5 to 8 for heavy commercial craft and racing boats)
St = Yield strength in torsional shear, in psi
rpm = Revolutions per minute of propeller shaft

Table 5-1

A

10–200 HP : Tobin Bronze

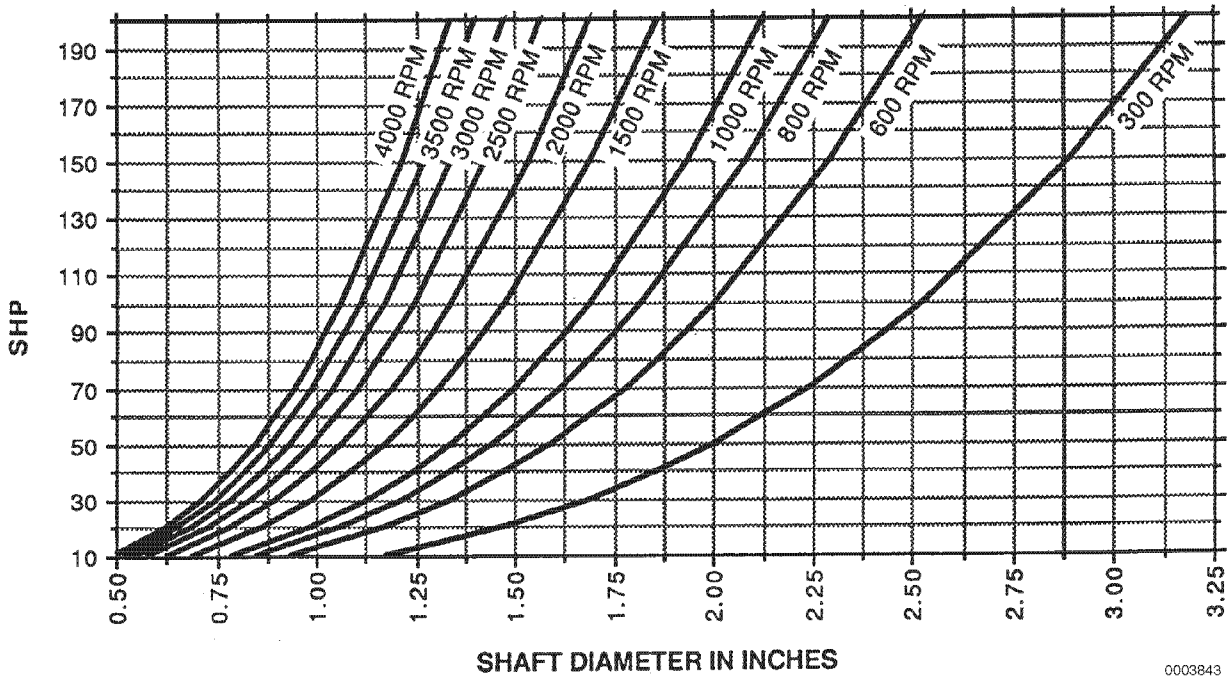


Table 5-2

B

200–500 HP : Tobin Bronze

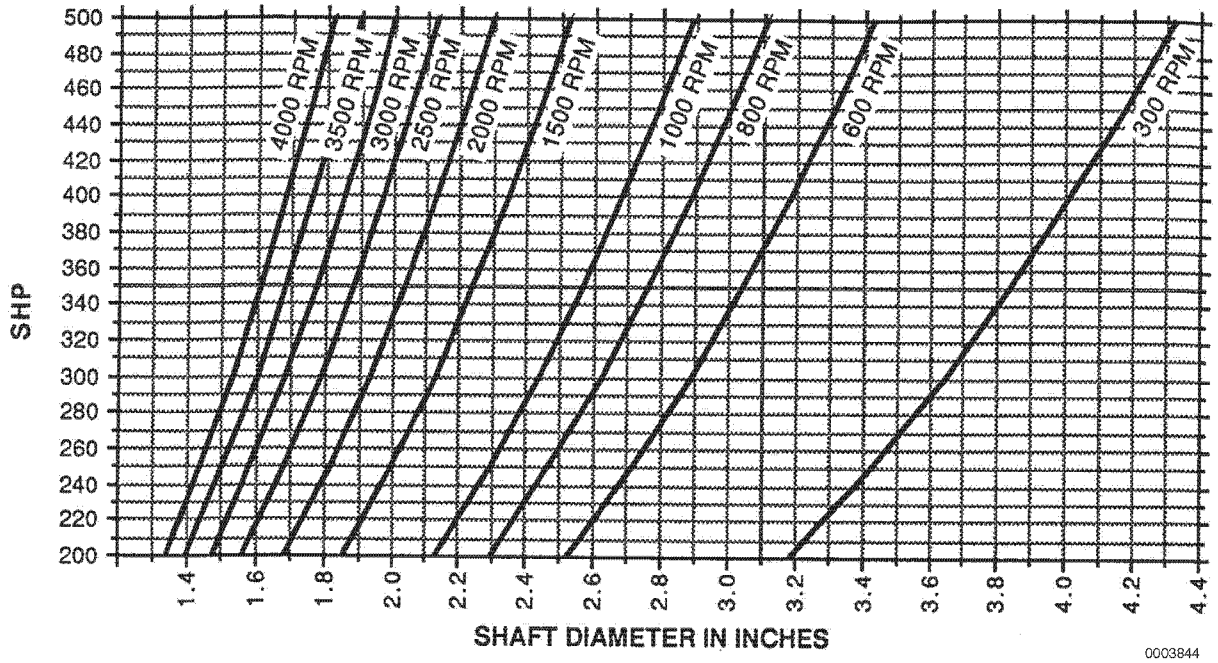


Table 5-3

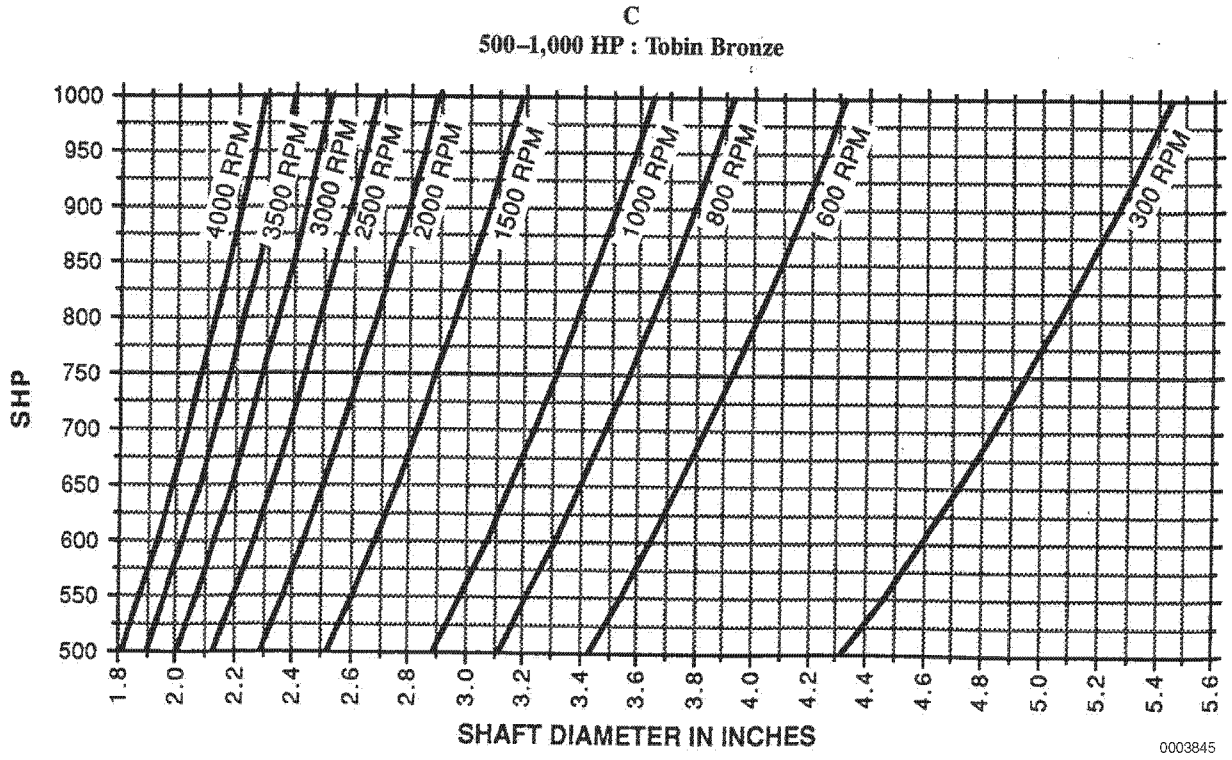
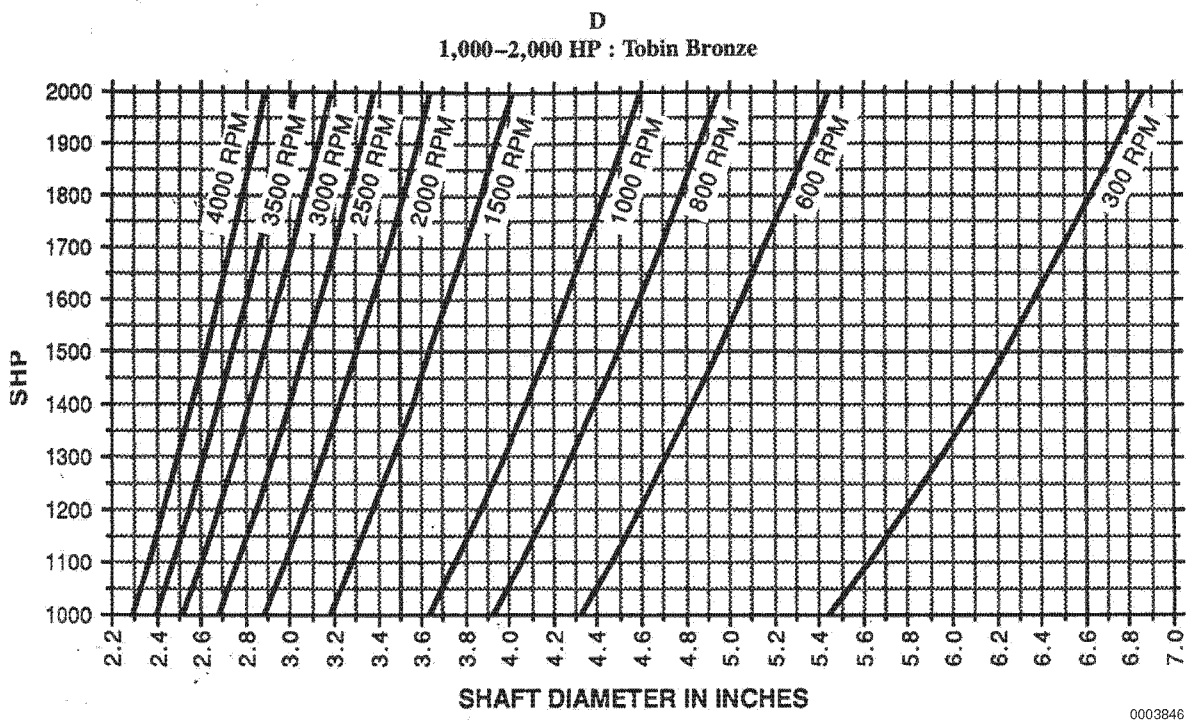


Table 5-4



Tables 5-1, 5-2, 5-3 and 5-4 are based on the shaft diameter formula. They show the proper diameter for tobin bronze propeller shafts at varying propeller shaft horsepower and propeller shaft rpm.

Table 5-1 uses a safety factor of three, which is most suitable for ordinary service, and the torsional shear strength of tobin bronze from Shaft Material Characteristics Table 5-2. Maximum attainable shaft horsepower and maximum attainable shaft rpm, after the reduction gear, must be used in determining propeller-shaft diameter.

The diameter for shafts of any suitable material and any desired safety factor can be calculated by inserting the appropriate value for the yield strength of that material and the desired value for safety factor in the shaft diameter formula.

TABLE 5-5 Shaft Material Characteristics

Shaft Material	Yield Strength in Torsional Shear, psi	Modulus of Elasticity, psi	Density lb/cu in.
Aquamet 22*	70,000	28,000,000	0.285
Aquamet 18	60,000	28,800,000	0.281
Aquamet 17	70,000	28,500,000	0.284
Monel 400	40,000	26,000,000	0.319
Monel K500	67,000	26,000,000	0.306
Tobin Bronze	20,000	16,000,000	0.304
Stainless Steel 304	20,000	28,000,000	0.286

*Aquamet 22 HS in diameters over 2.0 in.

High-Strength Alloys for Propeller Shafting

Nickel-copper offers high strength and corrosion characteristics. Since shafts made of alloys can have smaller diameters, their cost is not significantly greater than for ordinary tobin bronze shafts, and these materials should be employed in all heavy commercial vessels and racing boats. For ordinary small craft and light commercial vessels, tobin, manganese, silicone bronze or NAB bronze shafting is adequate, though cathodic protection against corrosion may be necessary.

Reduced Diameter for Intermediate Shafts

Where the propeller shaft is divided into a tail shaft that supports the propeller and an intermediate shaft or shafts, the intermediate shafts may be only 95 percent of the diameter of the tail shaft. Tables 5-1, 5-2, 5-3 and 5-4 and the shaft diameter formula can be used to calculate the tail-shaft diameter.

Shaft Bearings

Note: Make sure the propeller shaft bearing is installed within 1.2 m (3.9 ft) of the propeller shaft coupling.

The Twenty-Times / Forty-Times

Bearing Spacing Rule: The simplest rule for determining shaft-bearing spacing is that the bearings should be no closer together than twenty times the shaft diameter, and no further apart than forty times the shaft diameter. This rule is less reliable than the one-fourteenth rule for propeller shaft selection, and it should be used as a rough guide only. Very frequently, bearing spacing is considerably more than forty times the shaft diameter. Additional bearings simply add expense and unwanted shaft rigidity.

Determining Shaft-Bearing Spacing

The propeller shaft must be supported by intermediate shaft bearings, pillow blocks, between the flange coupling at the engine or gearbox and the stern bearing, unless the shaft is relatively short in proportion to its diameter. The shaft diameter formula gives the maximum spacing between shaft bearings for propeller shafts with flexible bearings at both ends. Most small craft have a rigid bearing at the engine and a rigid stern bearing, just ahead of the propeller. Such shafts should have maximum bearing spacings 50 percent greater than that given in the formula.

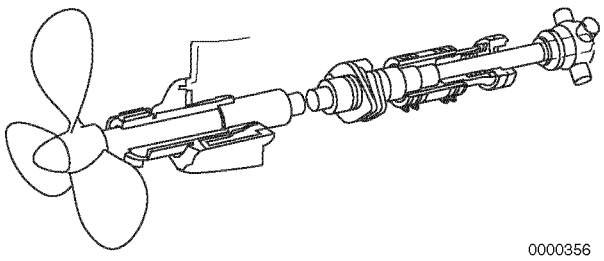


Figure 5-12

Distance Between Propeller Shafts for Twin-Engine Two Shaft Propulsion

The rough standard minimum distance between the outside diameters of two propellers should be more than 2.5 times the propeller's outside diameter. If the inter-shaft distance is too small, propeller efficiency, and therefore boat speed, will fall and excessive hull vibrations and other problems will result.

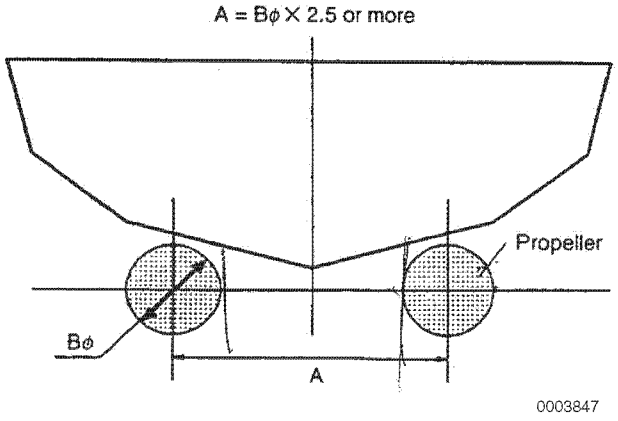


Figure 5-13

Engine Revolutions of Twin-Engine Installation

When building a boat for twin engine installation, it is difficult to distribute a strictly equal load balance between the port and starboard engines. It is also almost impossible to set the port and starboard engines with identical revolutions in a completed boat, for the following reasons:

(1) Fluctuations in engine performance.

(2) Fluctuations in tachometer performance.

(3) Fluctuations in propeller performance.

(4) Left and right imbalance in hull construction.

(5) Left and right imbalance in hull shape and weight when all inboard equipment, including fuel and water tanks and engines, is installed.

Notes: *Fluctuations of (1), (2) and (3) above are within standard allowable values.*

It is possible to adjust the revolutions of either engine to be nearly identical to those of the other using the results of the sea trial. However, this will shorten the life of the engine which receives the additional load.

Tip Clearance[1]

In general, it is important to use the largest diameter propeller possible. For single-screw vessels, diameter is limited by the size or height of the propeller aperture. On twin-screw craft, the diameter is limited by the shortest distance from the centerline of the shaft-strut bearing up to the underside of the hull. For a new design, this distance can be found by measuring from the buttock lines at the half-breadth of the propeller shaft, and cross-checking on the sections or body plane at the location of the strut and propeller. On an existing vessel, the distance can be measured directly. (Remember that the shortest distance may not be straight up. When measuring, swing your ruler through an arc centered at the shaft centerline. The shortest distance will often be found with the ruler angled slightly up and inboard.)

Once the maximum distance from the shaft centerline to the hull (and down to the skeg below, in an aperture) is known, the largest acceptable propeller diameter can be determined. Generally, there should be a *tip clearance* of at least 15% of the overall propeller diameter between the blade tips and the hull. The ideal tip clearance is 20% or more; however, additional tip clearance is usually found at the cost of the overall propeller diameter. Since smaller diameters mean lower efficiency, you are faced with a trade-off between the increase in efficiency from larger diameter and the increase in efficiency from improved water flow to the propeller and reduced vibration from greater tip clearance.

Actually, the slower the shaft rpm and the lower the boat speed, the lower the minimum tip clearance may be. Table 5-6 gives minimum tip clearances at varying rpm.

The clearances in Table 5-6 represent the absolute minimum, so you should always strive to do better. Tugs and trawlers frequently accept the additional vibration of propellers with only 8 - 10% tip clearance to gain additional thrust at low speed from increased propeller diameter.

TABLE 5-6 Minimum Tip Clearance

RPM	SL Ratio	Minimum Tip Clearance
200 - 500	under 1.2	8%
300 - 1800	1.2 - 2.5	10%
1000 and above	over 2.5	15%
High-speed planing craft	over 3.0	20%

[1] Dave Gerr, *Propeller Handbook* (Maine, International Marine, 2001).

PROPELLER MATCHING

The selection of a main engine for a boat is decided by the type of boat, hull size, hull weight and loading weight. The selection of an appropriate propeller that matches the output of the main engine is very important for the economical operation and durability of the engine.

When the propeller is too small for the engine output, there will be a loss in both engine output efficiency and boat speed. When the propeller is too large for the output, the engine will be overloaded at full throttle. Prolonged engine use at full throttle will cause engine damage.

The size of the propeller is determined at the design stage of the boat in consideration of the boat's speed and size, the shape and weight of the hull, main engine output, the reduction ratio of the marine gear and the maximum number of the crew (maximum loading weight). However, it is extremely difficult for a boat to be built strictly according to the design drawings. Accordingly, the final checks of the boat speed, propeller matching and other aspects of boat performance must be made by sea trials. If the boat's performance is unsatisfactory, it can be improved by changing the propeller specifications such as the number of blades, diameter, pitch and extended area ratio of blades.

It is easier to change the propeller than the engine or the shape of the hull.

The performance of fiberglass-hulled pleasure boats is especially likely to differ from that intended in the design. Experience is often the best guide in such situations. Boat building is still a very empirical form of engineering.

There are various ways to calculate the proper propeller size for pleasure boats, but there is no definitive formula. Contact the propeller manufacturer for more information.

Load measurement sea trial tests for estimating the load horsepower are made by measuring the engine's exhaust temperature under load. Special measuring equipment is used for the exhaust temperature. Consult with your Yanmar dealer if planning to conduct such measurements.

Tip: Recommended Propeller Matching Point; Continuous Rating Output at propeller shaft: 95 - 100%

Notes: To ensure appropriate propeller matching consider the following factors, (keeping some output in reserve):

- Increase of boat resistance due to contamination of hull.
- Increase of displacement due to increase of ship's fitting and crew.
- Horsepower required to drive auxiliary equipment such as generator set or pump set powered by the main engine (excluding auxiliary equipment not driven while the propeller is operated).
- Engine de-rating factors (factors that reduce engine output):
  - Lack of air intake volume
  - Excessive temperature (over 30°C [86°F])
  - Excessive exhaust back pressure
  - High temperature fuel

Simple Propeller Matching Procedure

It is possible to find if the propeller is too large for the engine output (i.e., the engine is overloaded) or too small (i.e., a loss of engine output) by the following simple procedure during the sea trial.

1. Check the engine's maximum speed (high idle) with no load.
   (a) Move the shift lever of the marine gear to NEUTRAL.
   (b) Raise the engine speed gradually with the engine speed control handle (remote control handle), moving the shift lever to the full throttle position.

(c) Check whether the engine speed at the full throttle position is within the no load maximum speed range.

Notes:

- Refer to the no load maximum engine speed in the applicable specification table in Volume 2 or 3.
- If the engine speed is below the no load maximum engine speed range, the problem is due to the absence of remote control stroke or faulty contact of the remote control cable.

2. Check the engine's maximum speed at load.

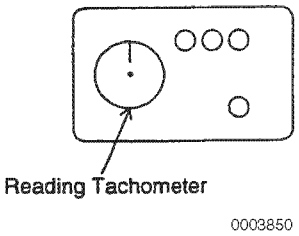


Figure 5-14

(a) Move the marine gear shift lever to FORWARD at the idling speed of the engine.

(b) Raise the engine speed gradually with the engine speed control handle (remote control handle) while moving the shift lever to the full throttle position.

(c) Check the loaded maximum speed at full throttle.

3. Compare both maximum rating engine speeds to the specified speed and the actual speed.

Notes:

Refer to the maximum output engine speed in the applicable specification table in Volume 2 or 3.

- If the engine speeds are within the range between maximum rating output and no load maximum engine speed, the propeller size is normal.
- If the no load and loaded maximum engine speeds are identical, the propeller is too small. There is unused engine output in reserve.
- If the engine speed is lower than the engine speed at maximum rating output, the propeller is too large. The engine will be overloaded at full throttle.

Do either of the following:

- ◆ Change to a smaller propeller.
- ◆ Keep the maximum service speed at approximately 50 - 100 rpm higher than the specified engine speed at maximum power (using a slightly smaller propeller).

PROPELLER POSITION (PROPELLER APERTURE)

This boat's full speed will not be obtained if the spacing between the propeller and hull is not equal to, or greater than, the value given in the figure. The position of the propeller selection shaft center must be at least one propeller diameter beneath the surface of the water with the boat fully loaded.

Recommended dimension
D = Propeller diameter
(a) = D x 0.12 more than
(b) = D x 0.15 more than
(c) = D x 0.12 more than
(d) = D x 0.08 more than

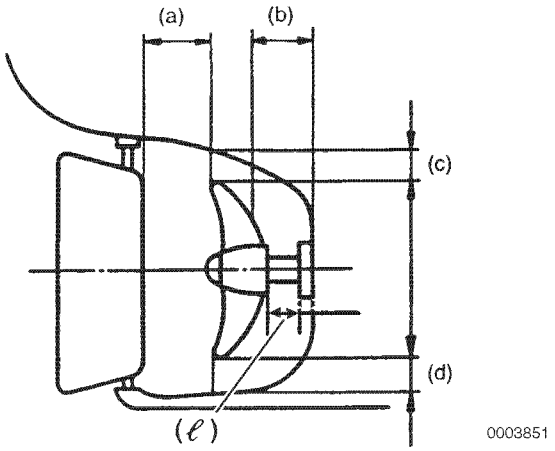


Figure 5-15

Note: With the engines with flexible engine mounts, the "ℓ" clearance should be more than 20 mm (0.79 in.). Shorter clearance may cause the propeller to interfere with the boat hull on astern operations due to the flexing of the flexible engine mounts.

SEA TRIALS

Confirming the appropriate propeller selection can only be accomplished through sea trials.

CAUTION

Sea trials can only be performed safely when the vessel is adequately manned. Do not attempt to collect and record performance data while operating a vessel alone.

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Sea Trial Test Procedure

The following steps represent a procedure for determining if the appropriate propeller is selected. If the propeller is too large for the engine output power, engine overloading results. If the propeller is too small for the engine output power, power losses are noted while the engine rpm approaches dangerously high levels.

Record critical engine rpm and vessel speed data with the *Sea Trial Worksheet on page 5-20*.

1. Refer to the *Service Manual* for the engine that is installed in the vessel and record the engine specification data (a-d) in the *Sea Trial Worksheet*.
2. Move the shift lever of the marine gear to the ***neutral*** position and start the engine.
3. Record the rpm data on the *Sea Trial Worksheet Data (e).*
4. Raise the engine rpm gradually to the ***full throttle*** position.
5. Record the rpm data on the *Sea Trial Worksheet Data (f).*
6. Lower the engine rpm to the ***idle*** position.
7. Move the shift lever of the marine gear to the ***forward*** position.
8. Record the rpm data on the *Sea Trial Worksheet Data (g).*
9. With a snap throttle motion, raise the engine rpm to the ***full throttle*** position.

10. On the *Sea Trial Worksheet,* record the time required for the vessel to reach planing - *Data (i).*
11. On the *Sea Trial Worksheet,* record the elapsed time required for the vessel to reach top speed *Data (j).*
12. Record the rpm data on the *Sea Trial Worksheet Data (h).*
13. Record the top speed data on the *Sea Trial Worksheet Data (k).*

Sea Trial Worksheet

Marine Gear and Throttle Position	Engine Specification	Sea Trial Data		
N/A	**Engine RPM Performance**	**Engine RPM Performance**	**Vessel Performance**	
			Snap Throttle Hole-shot Time	*Acceleration to Full Speed Time*
No Load Idle	_____rpm *Data (a)*	_____rpm *Data (e)*	*N/A*	*N/A*
No Load WOT (wide open throttle)	_____rpm *Data (b)*	_____rpm *Data (f)*	*N/A*	*N/A*
On Load Idle	_____rpm *Data (c)*	_____rpm *Data (g)*	*N/A*	*N/A*
Full Load WOT (wide open throttle)	_____rpm *Data (d)*	_____rpm *Data (h)*	_____ Seconds *Data (i)*	_____ Seconds *Data (j)* _____ Speed *Data (k)*

Section 6

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ELECTRICAL SYSTEM

⚠ DANGER

EXPLOSION HAZARD!

- Keep the area around the battery well-ventilated. While the engine is running or the battery is charging, hydrogen gas is produced which can be easily ignited.
- Keep sparks, open flame and any other form of ignition away while the engine is running or battery is charging.
- Failure to comply will result in death or serious injury.

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⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Only use the key switch to start the engine.
- NEVER jump-start the engine. Sparks caused by shorting the battery to the starter terminals may cause a fire or explosion.
- Failure to comply will result in death or serious injury.

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⚠ DANGER

EXPLOSION HAZARD!

- NEVER check the remaining battery charge by shorting out the terminals. This will result in a spark and may cause an explosion or fire. Use a hydrometer to check the remaining battery charge.
- If the electrolyte is frozen, slowly warm the battery before you recharge it.
- Failure to comply will result in death or serious injury.

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⚠ WARNING

BURN HAZARD!

- Batteries contain sulfuric acid. NEVER allow battery fluid to come in contact with clothing, skin or eyes. Severe burns could result. ALWAYS wear safety goggles and protective clothing when servicing the battery. If battery fluid contacts the eyes and / or skin, immediately flush the affected area with a large amount of clean water and obtain prompt medical treatment.
- Failure to comply could result in death or serious injury.

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⚠ WARNING

SHOCK HAZARD!

- Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.
- Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. ALWAYS keep the connectors and terminals clean.
- Failure to comply could result in death or serious injury.

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CAUTION

NEVER turn off the battery switch (if equipped) or short the battery cables during operation. Damage to the electric system will result.

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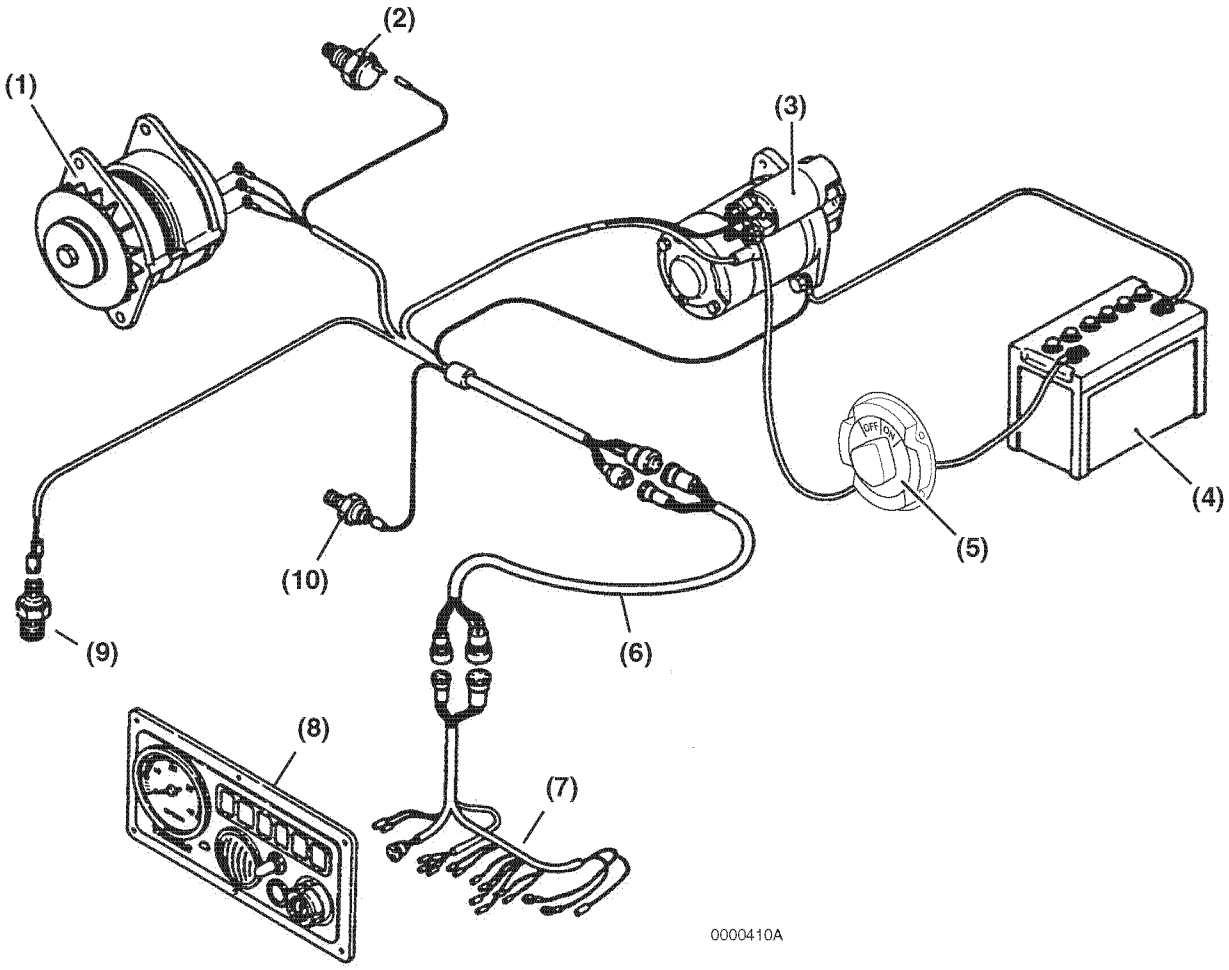
TYPICAL INSTRUMENT PANEL

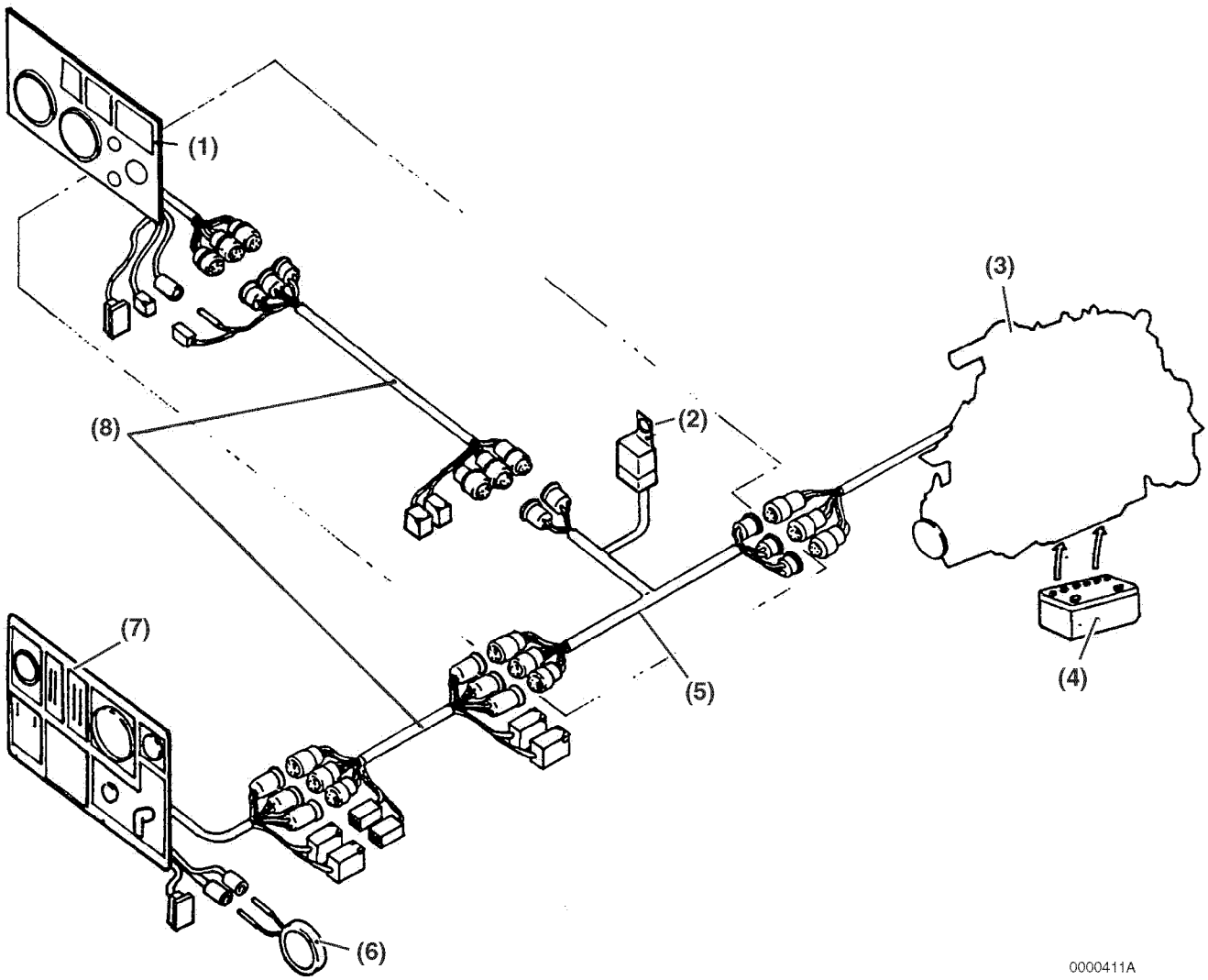


1 – Alternator
2 – Cooling Water Temperature Switch
3 – Starter Motor
4 – Battery
5 – Battery Switch
6 – Extension Wire Harness
7 – Wire Harness
8 – Instrument Panel
9 – Tachometer Sender
10 – Lubrication Oil Pressure Switch

Figure 6-1

Note: For details about wiring, refer to the wiring diagrams for the specific engine model in Volume 2 or 3.

Dual Instrument Panel



1 – Upper Bridge Instrument Panel (Option)
2 – Relay
3 – Standard Equipment
4 – Battery
5 – Wire Harness for Dual Instrument Panel (Option)
6 – Buzzer
7 – Main Bridge Instrument Panel (Option)
8 – Extension Wire Harness (Option)

Figure 6-2

Combination of Dual Instrument Panels

Note: Instrument panel combinations differ depending on the engine model. Please refer to the information for the specific engine model in Volume 2 or 3.

Wire Harness (Engine Side), Two-Pole Type

Two-Pole Type

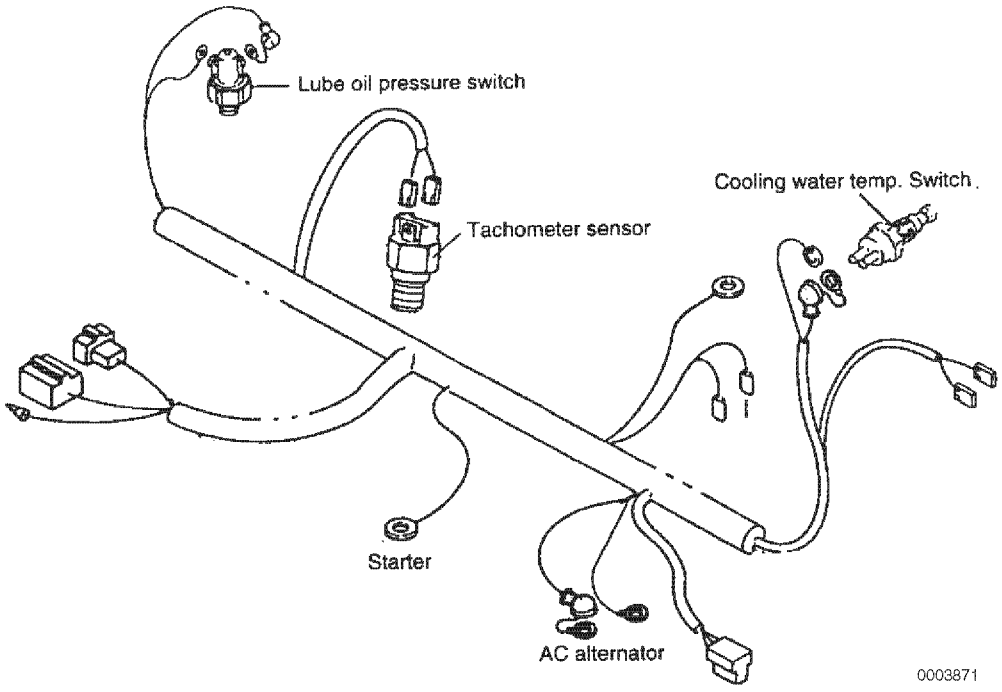


Figure 6-3

Applicable Instrument Panels

B2/New B, C/New C, D/New D and E-type

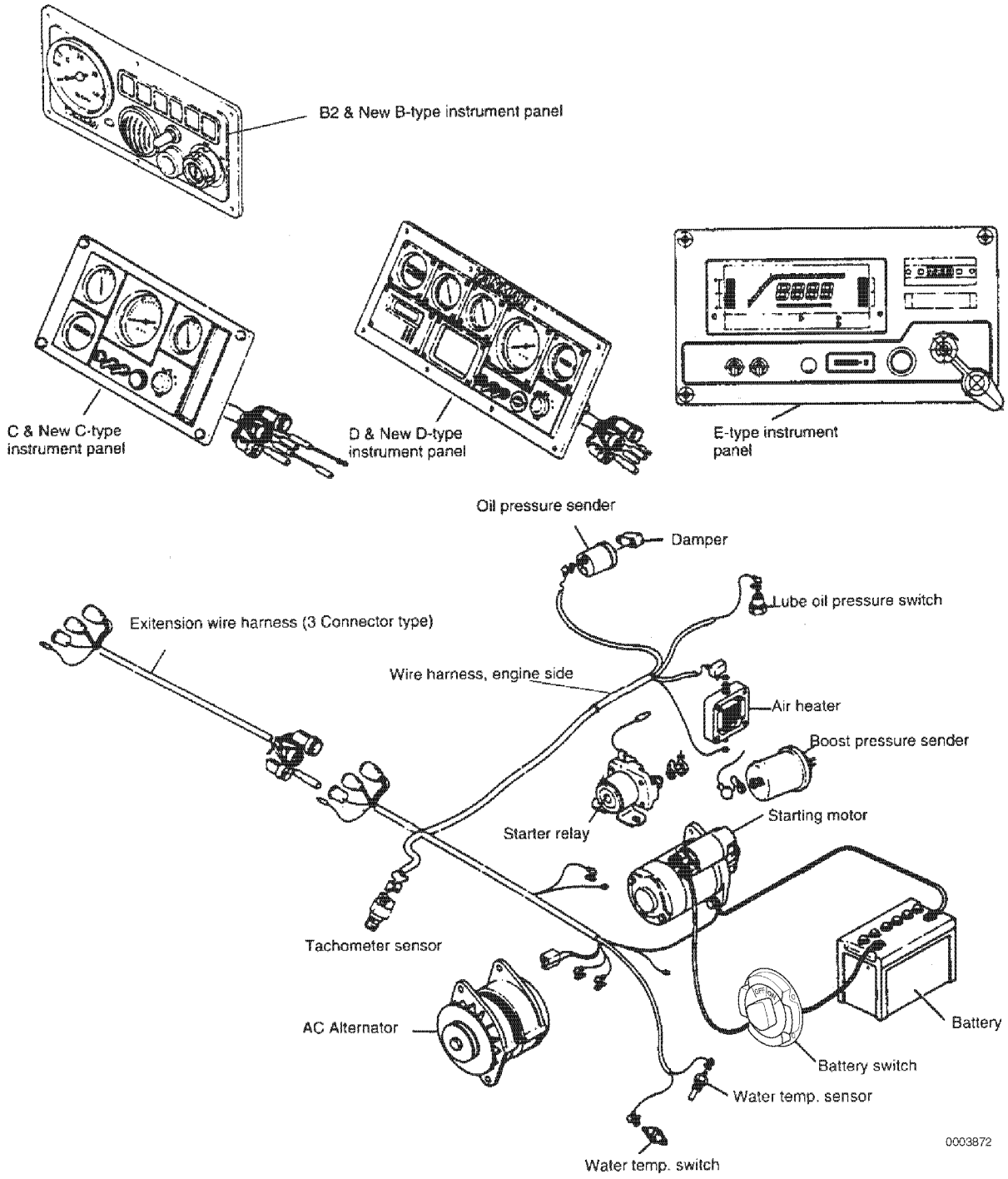


Figure 6-4

Wire Harness (Engine Side), Two-Pole Type

Two-Pole Type

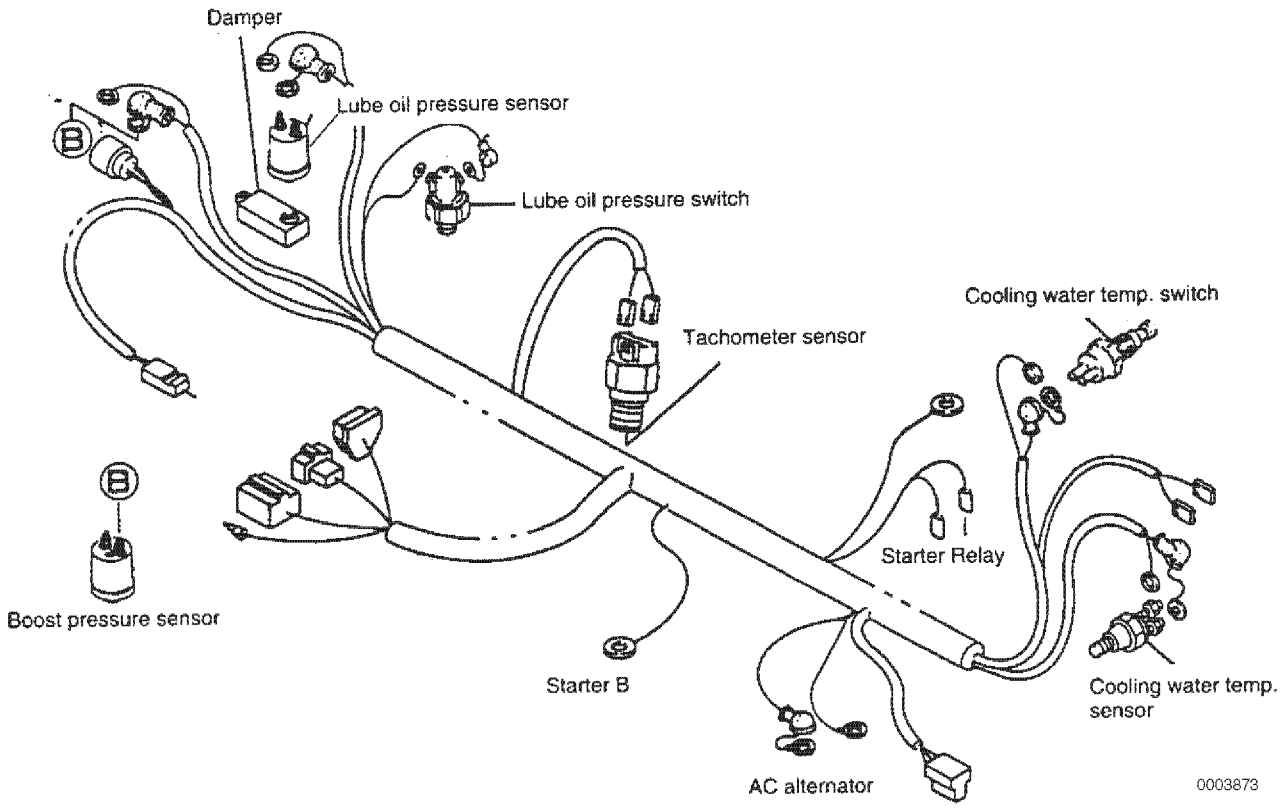


Figure 6-5

Electric Wire

Voltage Drop in the Wire

⚠ WARNING

FIRE HAZARD!

- **Undersized wiring systems can cause an electrical fire.**
- **Failure to comply could result in death or serious injury.**

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When electric current flows in a wire conductor, the voltage drops due to conductor resistance. The voltage entering the electric device (load side) is therefore lower than the voltage at the power source outlet.

The resistance of a wire is proportional to its length and inversely proportional to its diameter. That is, a wire which is too long or too small has a larger voltage drop.

The use of such a wire would require a wastefully high voltage at the power source, and could cause the power equipment to produce power in excess of its rated output. This would eventually shorten the life of the equipment. The excessive current could also damage the wire insulation and cause electrocution or fires.

Permissible Amperage in the Wire

As a current flows in the wire conductor, the temperature of the wire rises according to joule's law. Too much current (too high a temperature) will lower the insulation performance of the wire, shorten its life, and cause melting or burning. This could be a fire hazard.

1. Wires have maximum allowable conductor temperatures. Yanmar uses JIS (Japanese Industrial Standard) AV wire (low-voltage wire for automobiles).
2. AV wire: Allowable ambient conductor temperature 60°C and 80°C.

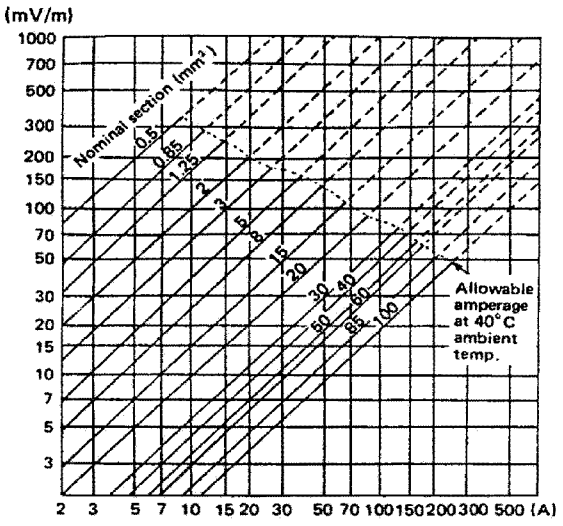
AV wire EXAMPLE: A V 5

- 5 — Wire size (mm^2)
- V — Vinyl (insulator)
- A — Automobile

Allowable Amperage and Voltage Drop of AV Wire

Ambient Temp	30°C		40°C		50°C	
	Allowable Amperage / Voltage Drop					
Nominal Section (mm²)	A	mV/m	A	mV/m	A	mV/m
0.5	11	414	9	338	6	226
0.85	15	356	12	284	8	190
1.25	19	310	15	245	10	163
2	25	251	20	201	14	140
3	34	216	28	178	19	121
5	46	185	37	149	26	104
8	60	158	49	129	34	90
15	82	129	66	104	46	72
20	109	110	86	87	61	62
30	152	90	124	73	87	51
40	170	83	139	68	98	48
50	195	75	159	61	113	43
60	215	70	175	57	124	40
85	254	62	207	51	146	36
100	294	56	240	46	170	33

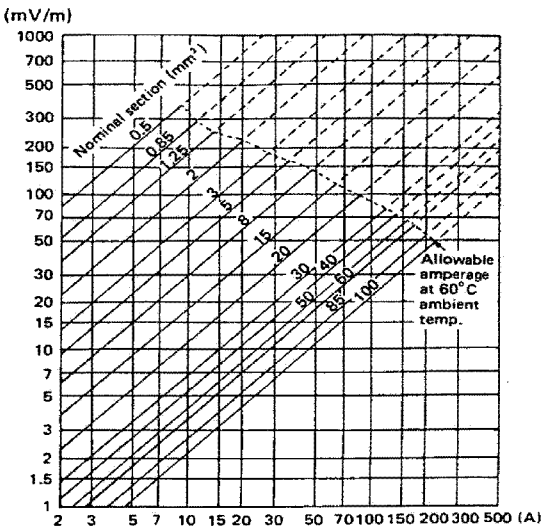
Ambient Temp	30°C		40°C		50°C		60°C		70°C	
	Allowable Amperage / Voltage Drop									
Nominal Section (mm²)	A	mV/m	A	mV/m	A	mV/m	A	mV/m	A	mV/m
0.5	14	561	12	481	11	441	9	361	6	263
0.85	18	456	16	406	14	354	11	278	8	202
1.25	23	400	21	365	18	313	14	244	10	174
2	31	332	28	300	24	257	20	214	14	150
3	42	285	38	258	33	224	27	183	19	129
5	57	243	51	218	44	188	36	154	25	107
8	75	211	67	188	56	163	47	132	33	93
15	102	171	91	153	79	133	64	108	45	76
20	136	196	132	131	106	114	86	93	61	66
30	190	120	170	107	147	93	120	76	85	54
40	213	110	190	98	165	86	134	69	95	49
50	244	99	219	89	189	77	154	63	109	44
60	268	93	240	83	208	72	170	59	120	42
85	318	83	284	74	246	64	201	52	142	37
100	368	75	329	67	285	58	232	47	164	34



AV wire (60°C) amperage and voltage drop

0000412

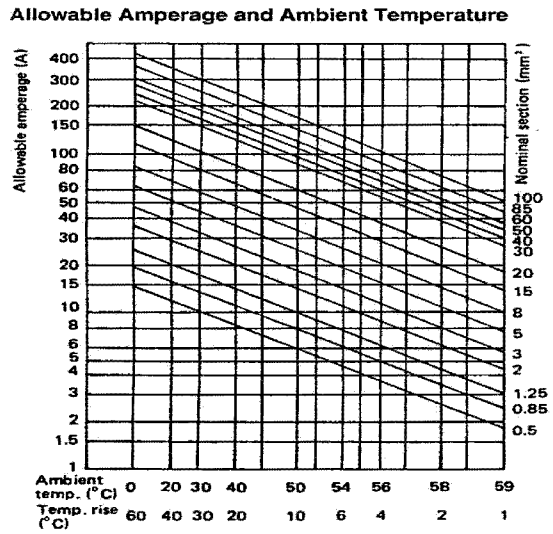
Figure 6-6



AV wire (80°C) amperage and voltage drop

0000414

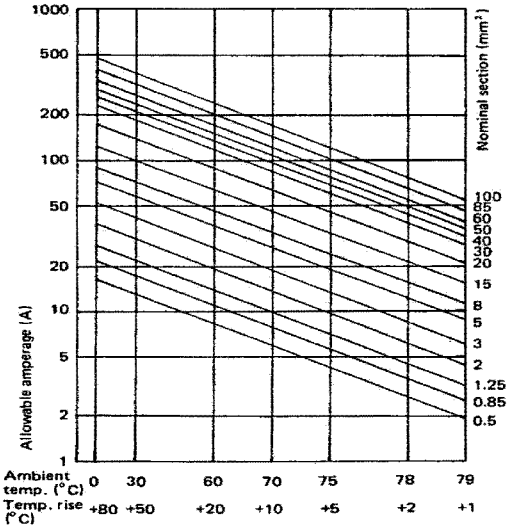
Figure 6-8



AV wire (60°C) ambient temp. and allowable amperage

0000413

Figure 6-7



AV wire (80°C) ambient temp. and allowable amperage

0000415

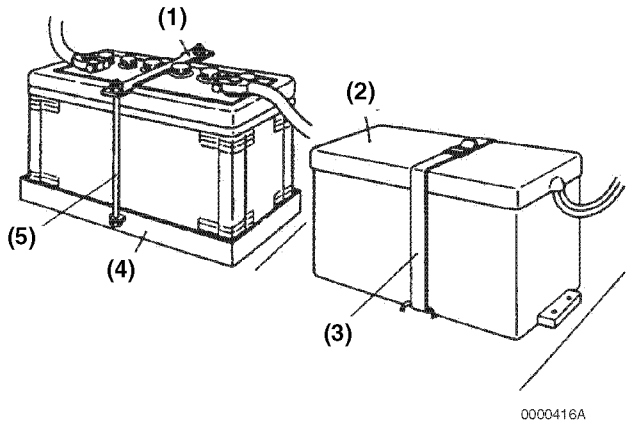
Figure 6-9

Batteries

A battery, or a system of batteries, provides electrical power for the engine and all DC electrical equipment on the vessel.

Installation

1. Install batteries in a well-ventilated location where no explosive gas can enter and where there is no possibility of acid corrosion.
2. Place batteries in an easily accessible location for inspection, replacement and wiring.
3. Use a battery box or frame to attach the battery to the hull. Use a bolt and clamp or a strap to secure the battery to the hull **(Figure 6-10)**.



1 – Clamp
2 – Battery Box
3 – Strap
4 – Battery Frame
5 – Frame Bolt

Figure 6-10

Battery Capacity

Required battery capacity varies depending on the amount and type of electrical equipment used in the vessel. For the engine's electrical equipment and its requirements, refer to the Engine Data for each model. For electrical equipment other than that needed for the engine, check the requirements for each unit and use an auxiliary battery as needed. See the Marine Installation Manual, Volume 2 and 3, for specific information on required battery capacity.

Battery Switch

⚠ WARNING

SHOCK HAZARD!

- **Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.**
- **Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. ALWAYS keep the connectors and terminals clean.**
- **Failure to comply could result in death or serious injury.**

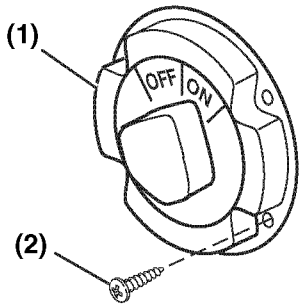
0000009en

CAUTION

NEVER turn off the battery switch (if equipped) or short the battery cables during operation. Damage to the electric system will result.

0000061en

The Yanmar battery switch, shown in **Figure 6-11**, is available as an option. The battery switch can be attached with the screws shown in the illustration.



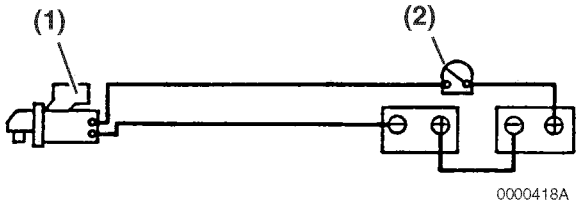
1 – Battery Switch **1 – Screw M8 x 38 mm**

Figure 6-11

Specifications

Type	BS500
Yanmar Part Number	D04211-77300
Rated Current	500A at starting, 50A at normal operation
Maximum Current	700A at 1 minute or 1000A at 20 seconds

1. Connect the battery switch to the positive (+) battery cable **(Figure 6-12)**.



1 – Starter Motor **2 – Battery Switch**

Figure 6-12

Note: Ensure that a battery switch is installed. If no battery switch is installed, the battery continues discharging while the boat is moored.

2. Install the battery switch in an easily accessible place near the battery. Do not attach the switch to the engine.
3. Do not place the battery switch in a place where the handle might be accidently touched or moved. If the battery switch accidently disconnects the battery circuit from the alternator circuit during engine operation, the IC regulator built into the AC alternator could be damaged.

Wiring the Battery

1. Connect the cable clamp on the red battery cable to the positive (+) battery post **(Figure 6-13)**.

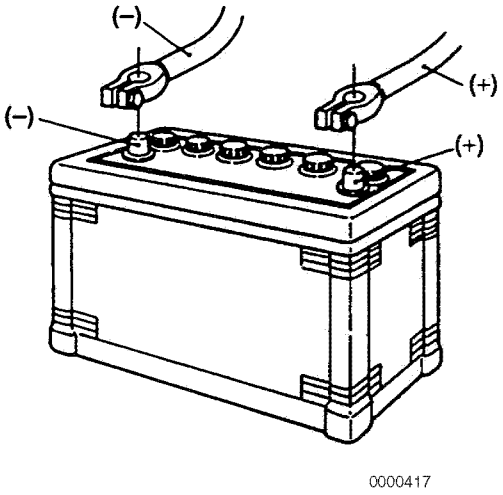


Figure 6-13

2. Connect the cable clamp on the black battery cable to the negative (-) battery post **(Figure 6-13)**.

IMPORTANT

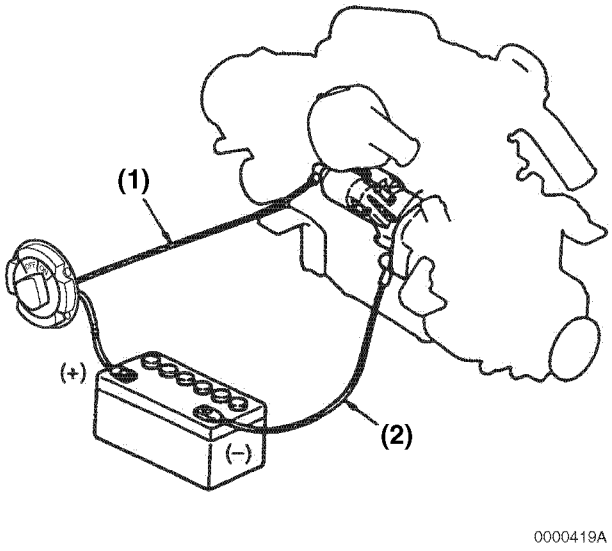
NEVER connect the positive (+) battery cable to the negative (-) battery post or the black battery cable to the positive (+) battery post. Doing so will damage the IC regulator that is built into the AC alternator.

3. When you select the battery cable for the application, choose a cable that corresponds to the rated voltage, rated output of the starter motor and whether or not a battery switch is used. *See Battery Cables on page 6-18.*

4. Apply grease to the battery terminals and connect the cable clamps to the battery posts **(Figure 6-14)**. Firmly tighten the cable clamp bolt to ensure good contact.

IMPORTANT

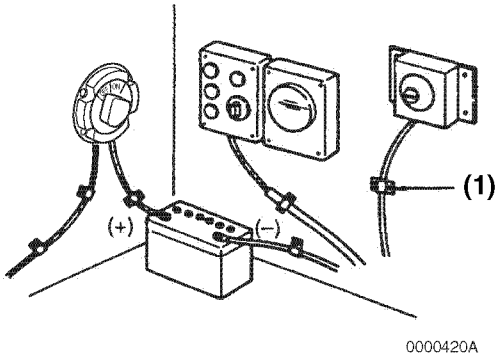
ALWAYS use a proper battery tester to check the battery current. NEVER use a metal tool, such as a screwdriver, to short across the battery terminals to check for current. ALWAYS remove the battery cables before quick-charging batteries.



1 – Positive (+) Battery Cable **2 – Negative (–) Battery Cable**

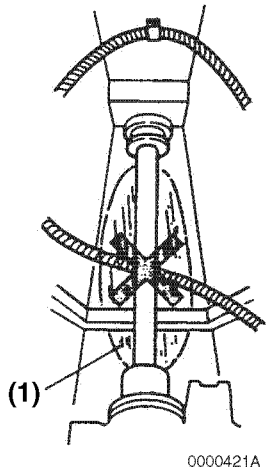
Figure 6-14

5. Secure the cables with clamps as needed to avoid damage from vibrations created by the hull of the boat **(Figure 6-15)**. Route the cables away from moving parts and make sure they do not lay in the bilge area **(Figure 6-16)**.



1 – Clamp

Figure 6-15



1 – Bilge

Figure 6-16

Battery Wiring Precautions

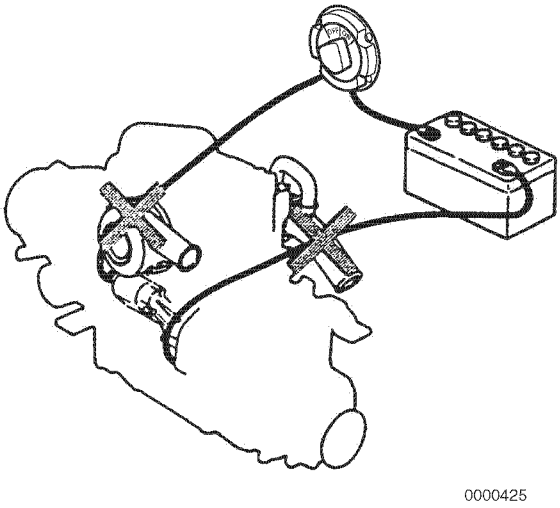


Figure 6-17

1. Route cables so they do not come in contact with sharp edges or heated areas.

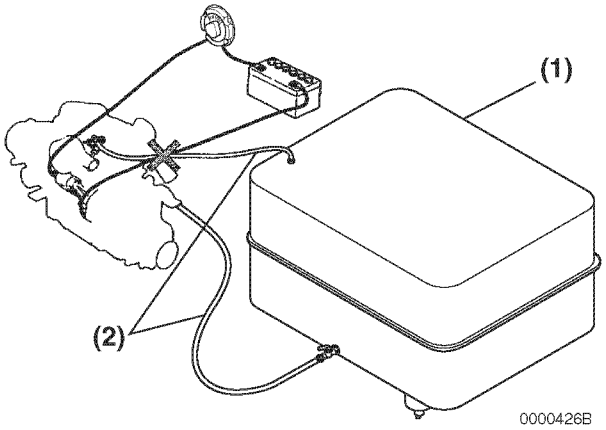


Figure 6-18

1 – Fuel Tank **2 – Fuel Lines**

2. Do not clamp the cables together with the fuel lines. Keep them away from the fuel lines.
3. Use wire of the correct size. Carry out correct wiring according to the wiring diagram for each model.

Battery Cables

Note: For the allowable cable diameter and length, refer to the engine wiring diagram for the specific engine model in Volume 2 or 3.

Allowable Maximum Length by Battery Cable Diameter (YIS Values)

Unit: m

Rated Voltage	12V			24V		Resistance of Wire (Ω m)	
Starting Motor Rated Output	Below 2kW	Over 2kW		Below 6kW	Over 6kW	AV, wire	IV, wire
Battery Switch / Nominal Section of Wire	with or without	without	with	with or without			
15 mm²	0.86	-	-	-	-	0.00188	-
20 mm²	1.3	-	-	-	-	0.000887	-
30 mm²	2.3	1.5	0.76	-	-	0.00052	-
40 mm²	2.8	1.8	0.9	2.8	-	0.000428	-
50 mm²	3.5	2.3	1.2	2.9	2.9	0.000337	0.000378
60 mm²	4.1	2.7	1.4	3.4	3.4	0.000287	0.000303
85 mm²	5.5	3.7	1.8	4.8	4.8	0.000215	-
100 mm²	7.1	4.7	2.4	6.0	6.0	0.000168	0.000180
125 mm²	-	5.5	2.8	6.9	6.9	-	0.000144
150 mm²	-	6.7	3.4	8.4	8.4	-	0.000118
200 mm²	-	8.6	4.3	10.8	10.8	-	0.0000922
250 mm²	-	-	-	13.8	13.8	-	0.0000722
Allowable Resistance of Wire	0.0012 Ω	0.0008 Ω	0.0004 Ω	0.001 Ω		-	

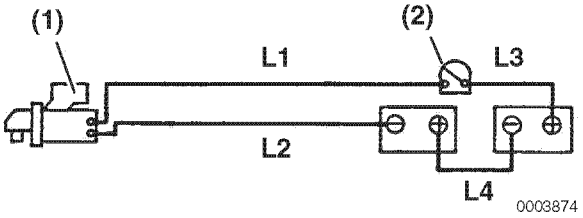
Note: AV wires are used for 15 -100 mm² and IV wires (600V vinyl insulated) for 125 - 250 mm².

Total Resistance of Battery Cable (YIS Formula)

$$L(m) = \frac{\text{Allowable wire resistance } (\Omega)^*}{\text{Resistance of the wire used } (\Omega/m)^*}$$

*The resistance varies depending on the wire standard of each country.

Note: The battery cable length, L(m), shows the full cable length of both the positive (+) and negative (-) cables (total of L_1 + L_2 +L_3 + L_4 in **Figure 6-19**).



1 – Starter Motor **2 – Battery Switch**

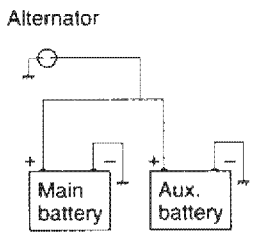
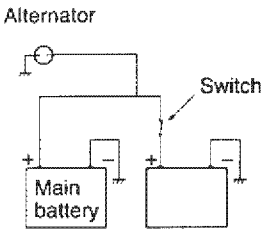
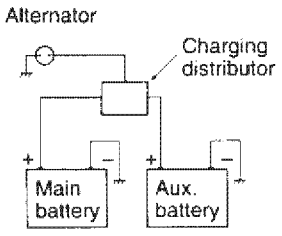
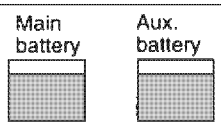
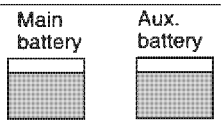
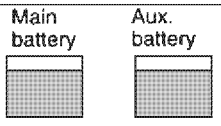
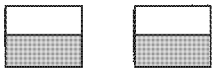
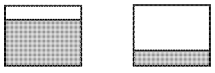
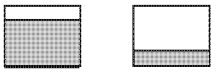
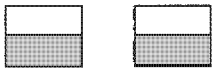
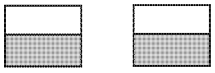
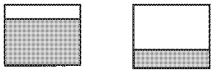
Figure 6-19

Multiple Battery Systems

Marine applications often require more than one battery to maintain sufficient power for onboard electric appliances, such as fans and refrigerators. Insufficient power can cause starter motor failure and alarm device malfunction.

Use a dedicated battery (main battery) for the engine's starter motor and alarm devices. Use a separate battery (auxiliary battery) for onboard electric appliances.

Adding a battery does not prevent main battery discharge unless a charging distributor (isolator) is integrated into the charging circuit. A properly installed charging distributor can charge both the main and auxiliary batteries concurrently from one alternator. This arrangement isolates reverse current flow. The diagram in **Figure 6-20** shows three multiple battery configurations.

	(1) Simple addition of battery	(2) Switch used	(3) Charging distributor used
Wiring			
Alternator (operating)			
Alternator (off) (Aux. battery operating)			
Starter started			
Remarks	Main battery discharges due to use of aux. battery.	Main battery discharges by turning on the switch for charging aux. battery.	Discharging from the main battery prevented.

0003878

Figure 6-20

Notes:

1. When adding a battery, check the battery capacity in respect to the alternator capacity. (Charging requires less time when the alternator capacity is small even if the battery capacity is increased.)
2. For wiring of a locally purchased charging distributor, consult the charging distributor or manufacturer and supply the information about the Yanmar engine alternator's characteristics, working circuit diagram and engine wiring diagram (including instrument panel wiring). Mis-wiring will cause malfunctioning of the engine's alarm circuits, alternator charging failure, etc.

Battery Charging Distributor (Isolator)

This item is explained for an external fan-type alternator and cannot be applied to an internal fan-type alternator.

Specifications

This specification shows samples of alternators for Yanmar engines.

Manufacturer		SAWAFUJI ELECTRIC CO., LTD		
Model Name		SBI-70	SBI-100	SBI-120
Rated Amperage		DC 70A	DC 100A	DC 120A
Rated Voltage		DC 12V	DC 12V	DC 12V
Dimensions L x W x H (mm)		76 x 114 x 90 mm 3.0 x 4.5 x 3.5 in.	120 x 114 x 90 mm 4.7 x 4.5 x 3.5 in.	140 x 114 x 90 mm 5.5 x 4.5 x 3.5 in.
Weight		410 g 14.4 oz	600 g 1.3 oz	710 g 1.6 lb
Loaded Characteristics at Ambient Temperature 55°C	Allowable Alternator Capacity	70A	100A	120A
	Continuous Load Ampere	DC 56A	DC 80A	DC 96A

When the ambient temperature rises above 55°C, the current gradually drops in the battery charging distributor. In such conditions, it is necessary to use a battery charging distributor with a one grade higher capacity.

Battery Charging Distributor (Isolator), Ambient Temperature - Current Drop Diagram

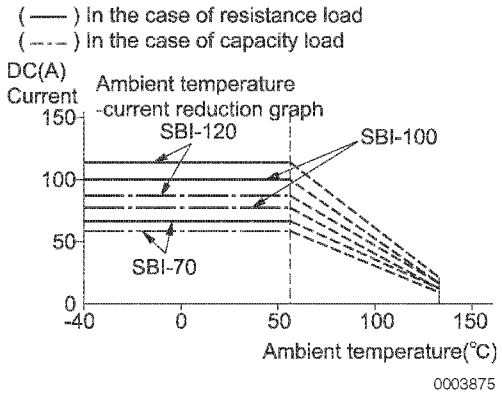


Figure 6-21

Installation

1. Install the battery charging distributor so that the cooling plate is perpendicular.

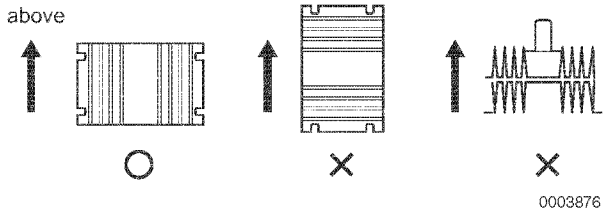


Figure 6-22

Note: If the installation shown above is impossible, use a battery charging distributor with a one grade higher capacity.

2. Install the distributor in a dry, well-ventilated location.
3. The battery charging distributor is heated during charging (100-110°C). Be sure to install it on a thick iron plate (3 - 5 mm). Do not touch the distributor while it is being charged.

4. Use the metal pressure-fit terminals to connect the wires to the battery charging distributor. Ensure correct connections.
5. Use the wire size suitable for the electric load of the wiring.

Circuit Diagram of Battery Charging Distributor (Isolator)

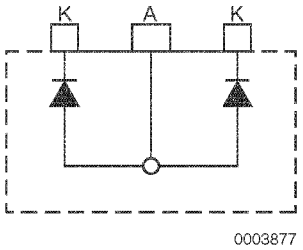
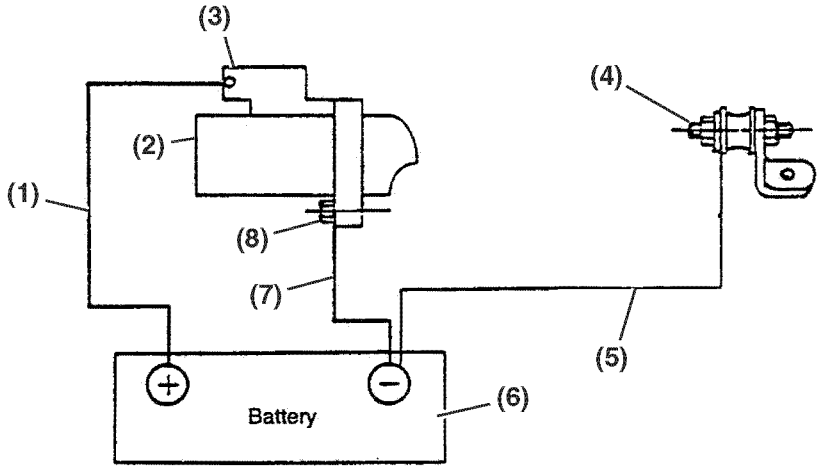


Figure 6-23

Two-Pole Wiring

The Yanmar 12V two-pole wiring system is a semi-two pole system that becomes an earth float system during engine operation, but not when starting. This helps to prevent electrolytic corrosion.



1 – Battery Positive (+) Cable (Red)
2 – Starter Motor
3 – Solenoid
4 – Earth Terminal (Earth Terminal Bolt)
5 – Ground Cable
6 – Battery
7 – Battery Negative (-) Cable (Black)
8 – Starter Mounting Bolt

Figure 6-24

Battery positive (+) cable **(Figure 6-24, (1))** and connection on the solenoid **(Figure 6-24, (3))**: Use a battery cable with the recommended diameter for each model.

Starter motor **(Figure 6-24, (2))** and battery negative (-) cable **(Figure 6-24, (7))**: Starter current flows only when the engine is started. Connect the battery negative (-) cable to starter mounting bolt to minimize the leakage of current to the engine and hull. Use a battery cable with the recommended diameter for each model.

Earth terminal **(Figure 6-24, (4))** and battery negative (-) cable **(Figure 6-24, (7))**: Attach the engine operation earth line between the earth terminal and battery (-). DO NOT connect the earth terminal to starter earth.

Note: Not applicable to meter sensor assembly for dual instrument panel type New C+C and New C+D combinations.

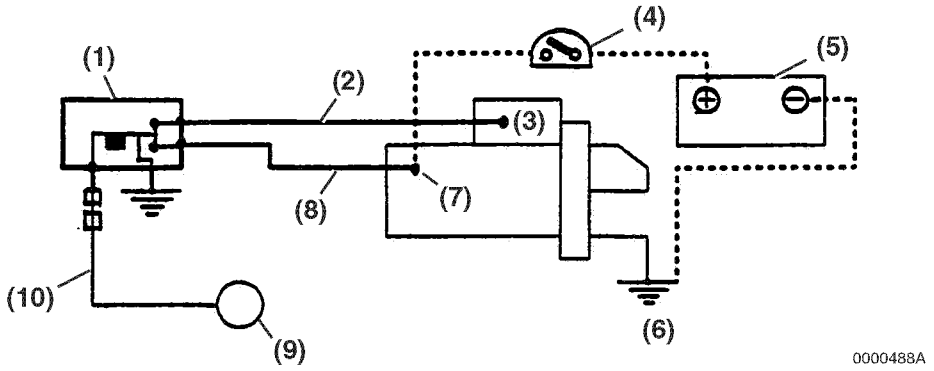
STARTER RELAY

Limit the length of extension wire harness within 6 m (19.5 ft) (for engine models without a starter relay connection to the starter circuit).

IMPORTANT

Starting failure can result due to voltage drop if an extension wire harness longer than 6 m (19.5 ft) is directly connected without using the starter relay.

Wiring for Starter Relay



1 – Starter Relay
2 – Red
3 – S
4 – Battery Switch
5 – Battery
6 – Earth Bolt
7 – B
8 – Red
9 – Starter Switch
10 – White

Figure 6-25

Specifications

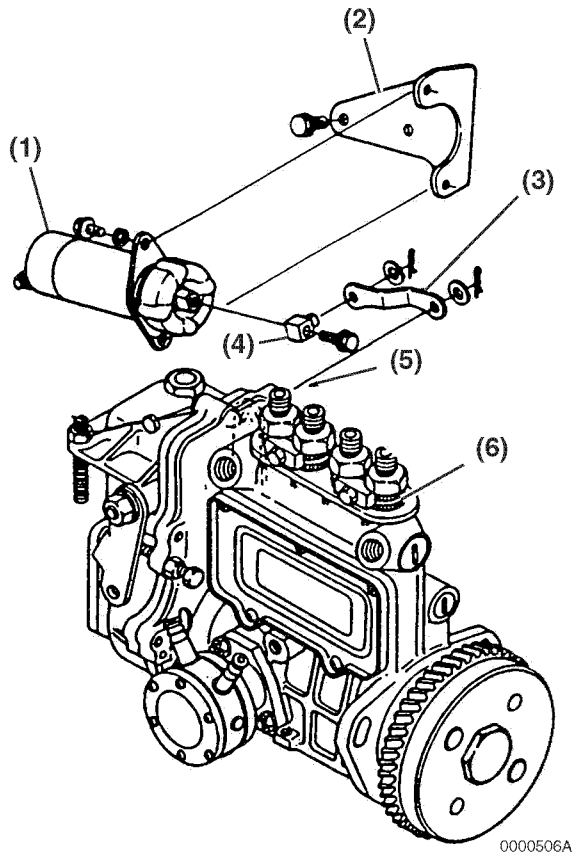
Yanmar Part Number	129490-77910
Rated Voltage	DC 12V
Rated Load	80A at 30 seconds 240A at instantaneous
Minimum Operation Voltage	below DC 8V at 20°C
Release Voltage	below DC 4V at 20°C
Exciting Current	below 4A at 12 V

Note: The standard accessory for the JH3 series engines changed at the end of March 1999.

ENGINE STOP SOLENOID

The stop lever of the fuel injection pump is connected to the solenoid with a connecting rod.

The device is operated by the stop switch on the instrument panel.

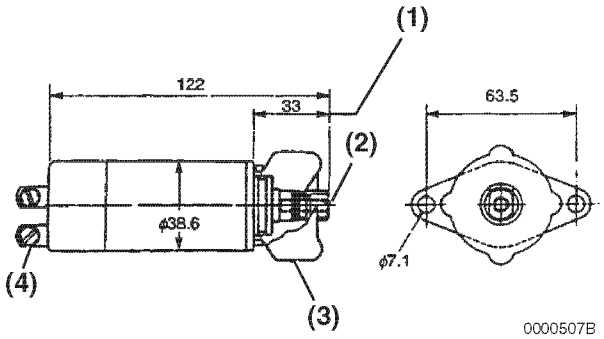


1 – Engine Stop Solenoid
2 – Solenoid Bracket
3 – Link
4 – Pin
5 – Engine Stop Lever
6 – Fuel Injection Pump

Figure 6-26

Solenoid Specifications

Type	ES1
Solenoid Model	1504-12A7U1B
Rated Voltage	12V
Loaded Current	41A
Holding Force	9 kgf at 25°C
Holding Current	0.75A
Pulling Force	5 kgf at 25°C



1 – When the Current Flows
2 – M6 Screw Depth 20.8
3 – Constant Volume Boot
4 – 8-32 Screw Terminal

Figure 6-27

Unit: mm

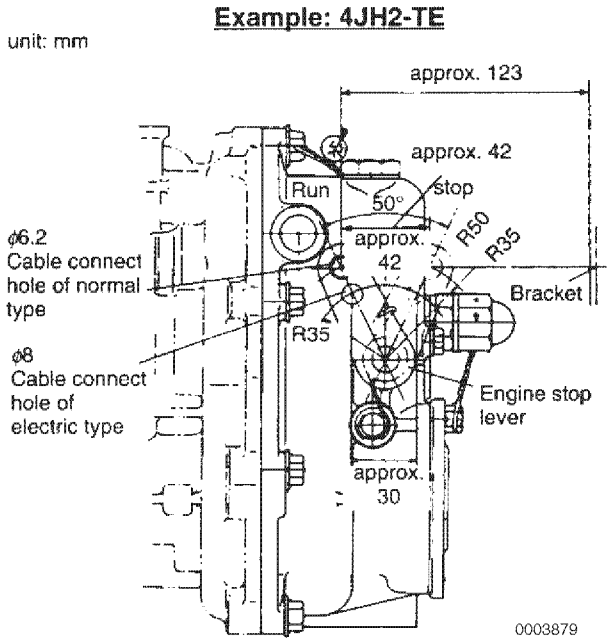


Figure 6-28

Relay

Rated Voltage	12 V
Contact Current	Lamp: 20A, Extra Lamp: 25A
Range of Operation	-30 - +90°C -22 - +194°F
Yanmar Part Number	124617-91850

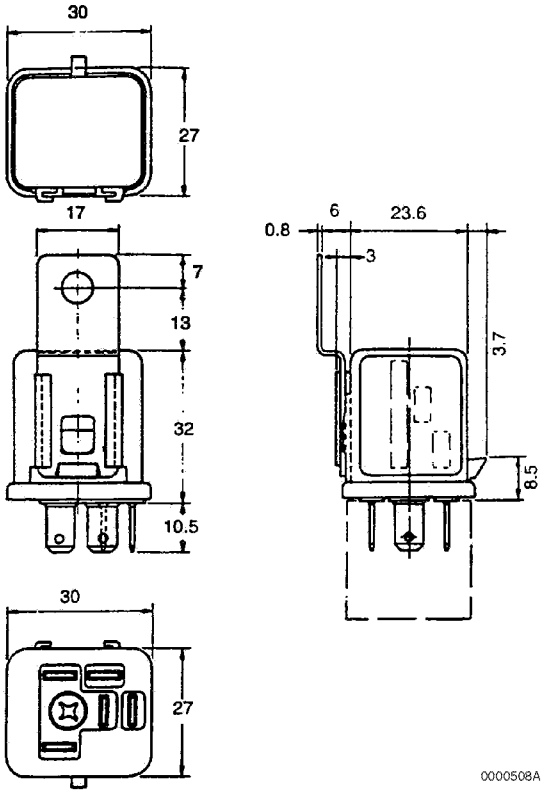


Figure 6-29

SENSOR UNITS

Sensor Assembly by Instrument Panel

Type of Instrument Panel / Sensor and Alarm Switch	A-type	B-type	B2 and New B		C and New C		D and New D		E-type
			B2	New B	C	New C	D	New D	
1. Tachometer Sensor	X	O	O	O	O	O	O	O	O
2. Alarm Switch									
• Cooling Water Temperature	O	O	O	O	O	O	O	O	O
• Lube Oil Pressure	O	O	O	O	O	O	O	O	O
• Sail Drive Seal Leak	O	O	O	O	O	O	X	X	X
• *Lube Oil Pressure For Marine Gear	X	X	O	O	O	O	O	O	O
• *Cooling Water (Closed Cooling) Level	X	X	X	O	X	O	X	O	X
• *Seawater Flow	X	X	X	O	X	O	X	O	X
• *Fuel Filter (Water Level)	X	X	O	O	O	O	O	O	O
• *Boost Pressure High	X	X	X	O	X	O	X	O	X
3. Meter Sensor									
• Lube Oil Pressure	X	X	X	X	O	O	O	O	O
• Cooling Water (Closed Cooling) Temperature	X	X	X	X	O	O	O	O	O
• *Boost Pressure	X	X	X	X	X	X	O	O	O

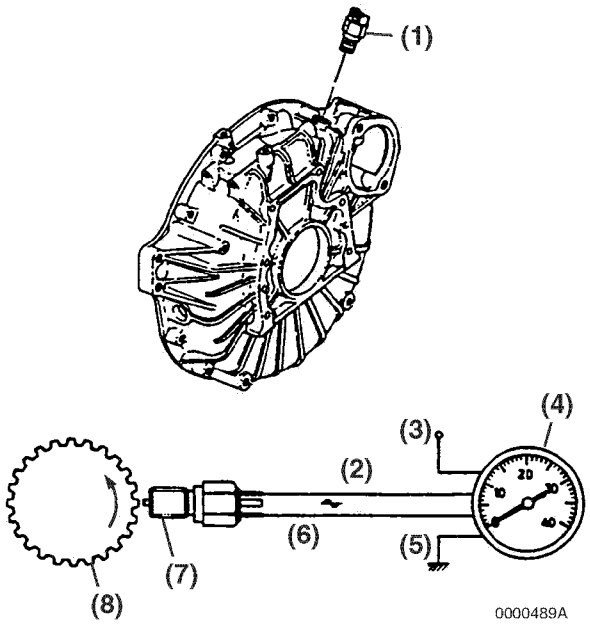
**Differs by engine model. Refer to the specific engine model information for available equipment.*

Note: 1. O = Equipped on panel. X = Not equipped on panel.

Tachometer

The tachometer indicates the number of revolutions per minute by means of an electrical input signal that is generated as a pulse signal from the magnetic pickup sensor.

The function of the sensor is to convert the rotary motion into an electrical signal by means of counting the number of teeth of the ring gear connecting with the flywheel housing.



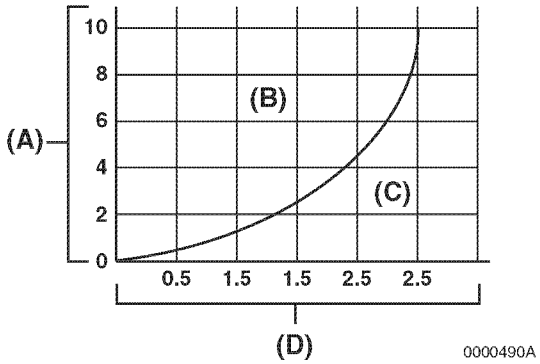
1 – Tachometer Sensor
2 – Orange
3 – Red/Black
4 – Tachometer
5 – Black
6 – Blue/Red
7 – Rotation Detecting Sensor
8 – Ring

Figure 6-30

Specifications

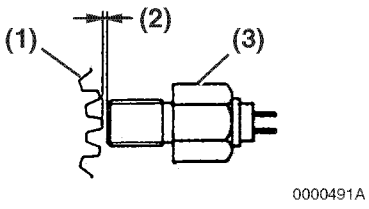
Rated Voltage	DC 12V
Range of Operating Voltage	10 - 15 V
Illumination Lamp	3.4 W/12V

Sensitivity Limit of Sensor Unit



A –Ring Gear Speed (m/sec)
B –G Zone
C –NG Zone
D – Sensor Unit and Ring Gear Clearance (mm)

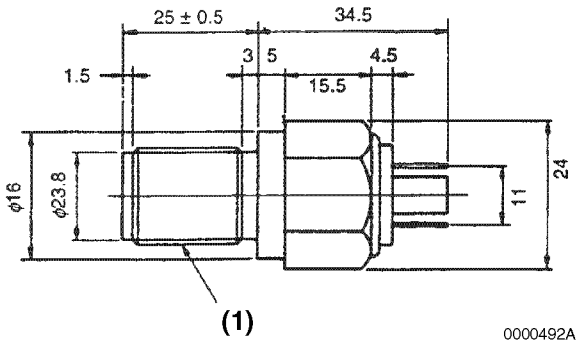
Figure 6-31



1 – Ring Gear
2 – Clearance
3 – Sensor Unit

Figure 6-32

Dimensions of Sensor



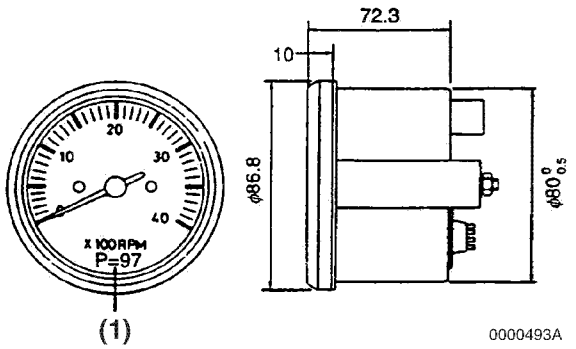
1 – M18 x P1.5

Figure 6-33

Unit: mm

Tightening torque of sensor: 5 kgf-m (49 N·m) (36.2 ft-lb)

Dimensions



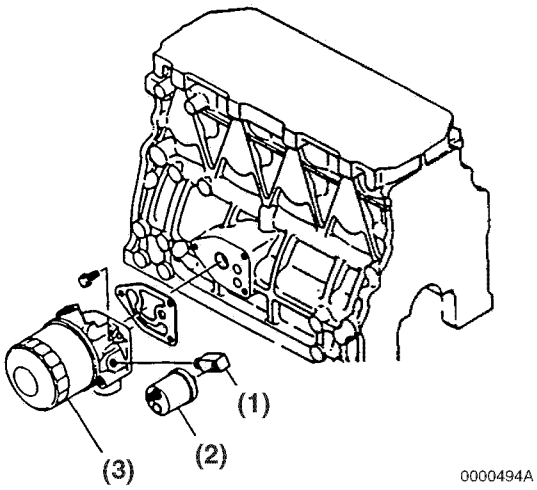
1 – Identification Mark

Figure 6-34

Unit: mm

Engine Oil Pressure Gauge Sensor

A sensor unit for engine oil pressure gauge is mounted on the oil filter bracket for some engine models. Oil pressure is measured when the oil enters the main gallery after being fed from the oil cooler and passing through the oil pressure control valve. Be sure to mount a vibration damper when mounting the oil pressure sensor unit.



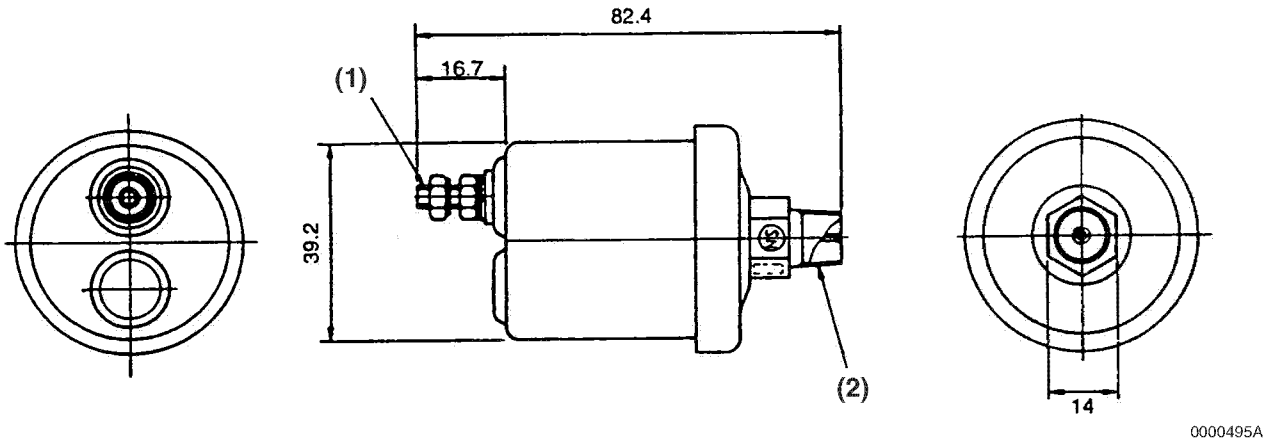
1 – Damper
2 – Engine Oil Pressure Sensor Unit
3 – Engine Oil Filter

Figure 6-35

Specifications and Dimensions

Note: New design sensors are interchangeable with existing sensors.

	Existing Sensor		New Design Sensor	
Type	Single Meter	Dual Meter	Single Meter	Dual Meter
Rated Voltage	DC 12/DC 24	←	←	←
Maximum Operating Pressure	800 kPa (8 kgf/cm²) (116 psi)	←	←	←
Yanmar Part Number	144626-91560	129574-91560	119773-91501	129574-91561
ID Mark/ID Color	LP/Silver	NS2/Silver	LP1/Gold	8KT/Gold



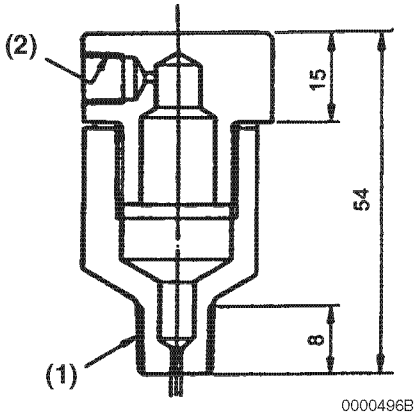
1 – M5 x P0.8 **2 – PT 1/8**

Figure 6-36

Unit: mm

Damper

4LH-DTE, 4LH-STE

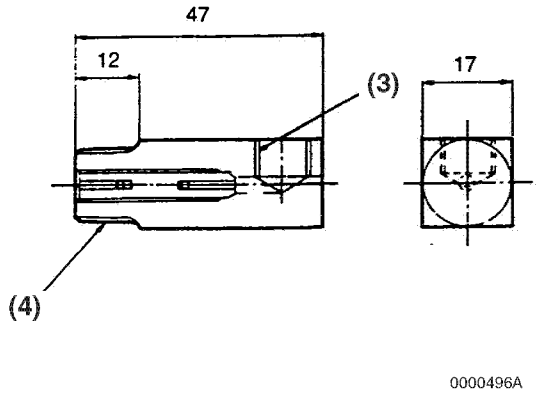


1 – PT 1/8
2 – PT 1/8

Figure 6-37

Unit: mm

JH2, LY, CX, 4LH-TE, 4LH-HTE



3 – PT 1/8
4 – PT 3/8

Figure 6-38

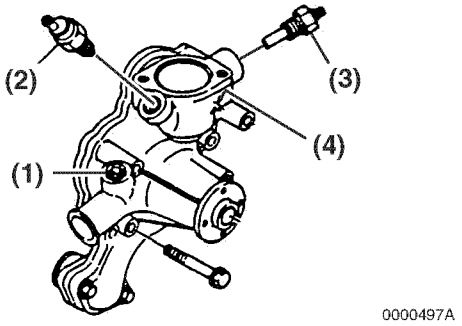
Unit: mm

Closed Coolant Temperature Sensor

The closed coolant temperature sensor should be installed where the highest expected coolant temperature will be, such as the thermostat housing, etc.

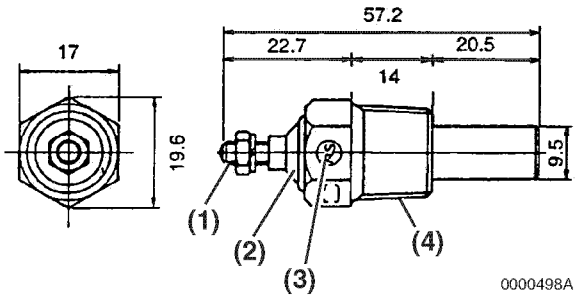
Specifications and Dimensions

Type	Single	Dual
Rated Voltage	12V / 24V	←
Yanmar Part Number	144626-91570	129574-91570



1 – Inlet for Water Heater
2 – Cooling Water Temperature Switch
3 – Cooling Water Temperature Sensor Unit
4 – Outlet for Water Heater

Figure 6-39



1 – M5 x P0.8
2 – Black Insulator Material
3 – ID Mark 2 of Dual Meter Sensor
4 – PT 3/8

Figure 6-40

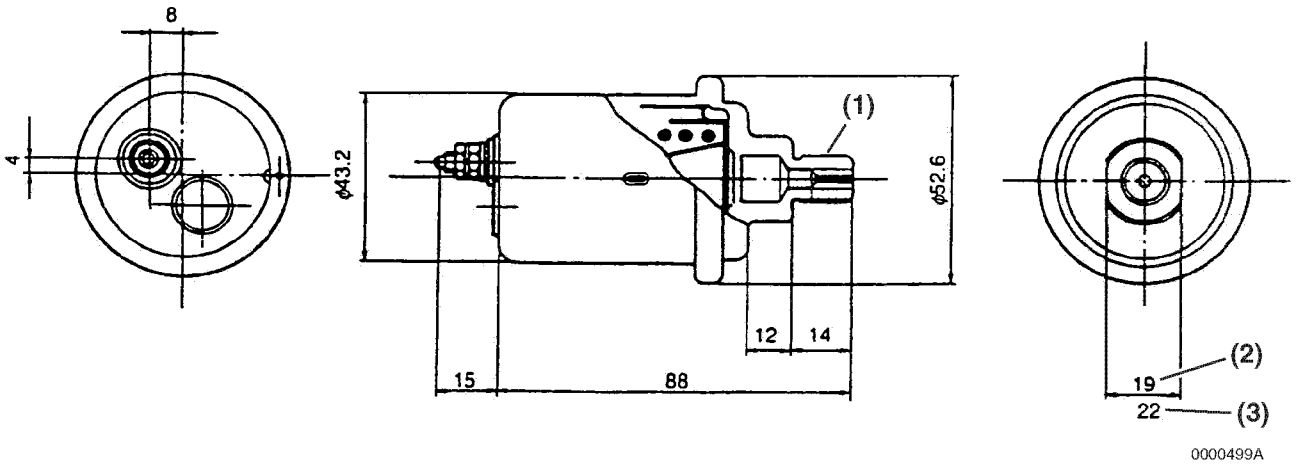
Unit: mm

Turbocharger Boost Pressure Sensor

Specifications and Dimensions

Note: New design sensors are interchangeable with existing sensors.

	Existing Sensor		New Design Sensor	
Type	LH	LY/CX	LH	LY/CX1
Rated Voltage	DC 12V/DC 24V	←	←	←
Maximum Operating Pressure	200 kPa (2 kgf/cm²) (29 psi)	300 kPa (3 kgf/cm²) (43.5 psi)	200 kPa (2 kgf/cm²) (29 psi)	300 kPa (3 kgf/cm²) (43.5 psi)
Yanmar Part Number	124413-91300	119773-91300	124413-91301	119773-91301
ID Mark/ID Color	-/Black	LP/Black	2K/Gold	3K/Gold



1 – M12 x P1.25 **2 – LH-type** **3 – LY/CX-type**

Figure 6-41

Unit: mm

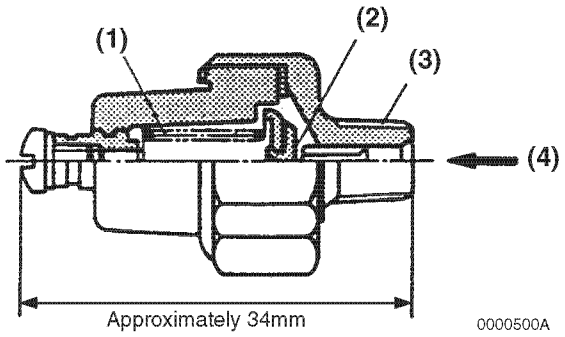
ALARM SWITCHES

Engine Oil Pressure

If the engine oil pressure drops with the key switch ON, the contacts of the oil pressure switch are closed by a spring, the lamp is lit and the audible alarm sounds at the instrument panel. If the oil pressure returns to normal, the switch contacts are opened and the lamp and the audible alarm turns OFF.

Specifications

Operating Pressure	0.1 - 0.3 kgf/cm^2 (0.014 - 0.043 psi)
Rated Voltage	DC 12V
Lamp Capacity	5 W
Yanmar Part Number	124060-39451

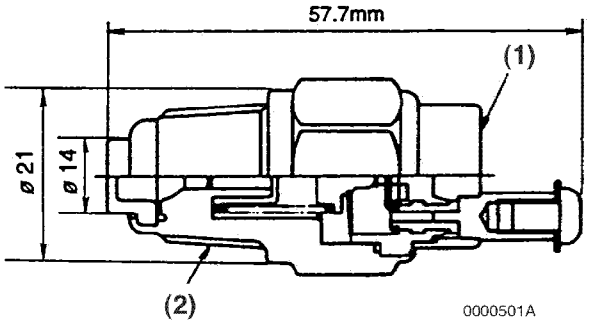


1 – Spring
2 – Contacts
3 – PT 1/8
4 – Oil Pressure

Figure 6-42

Closed Cooling System Temperature Switch

If the engine coolant is too hot with the key switch ON, the high-thermal expansion material contacts with the end of the cooling water temperature switch, the lamp is lit and the audible alarm sounds at the instrument panel.



1 – Identification Color
2 – PT 3/8

Figure 6-43

Specifications

Operating Temperature	ON	63 - 67°C 145 - 153°F	93 - 97°C 199 - 207°F	97 - 103°C 207 - 217°F
	OFF	58 - 63°C 136 - 145°F	88 - 93°C 190 - 199°F	90 - 97°C 194 - 207°F
Rated Capacity		DC 12V, 1A		
Response Time		within 60 seconds		
Operating Temperature Range		-97 - 130°C -142 - 266 °F		
Identification Color		White	Green	Black
Yanmar Part Number		128275-91340	127610-91350	120130-91370
Applicable Engine Type		Direct Seawater Cooling Type	Fresh Water Cooling Type	Fresh Water Cooling Type (JH2 Engine Series)

Note: Tightening torque of PT 3/8 thread: 240 - 320 kgf-cm (23.5 N·m) (17 ft-lb).

Fuel / Water Separator Water Level Switch

The fuel / water separator separates water from the fuel. The separated water drains to the bottom of the fuel filter. When the water exceeds a certain level, the water level switch turns the warning lamp on and sounds the audible alarm to alert the operator that water must be drained from the filter.

Specifications

Fuel Filter		
Filtration Volume	cm^2	3200
Rated Flow Volume	L/min.	2
Maximum Water Reservoir	mL	300
Water Level Switch		
Rated Voltage	V	12
Operative Position of Water Level	mL	ON: 80 - 120
Yanmar Part Number: 119773-55500		

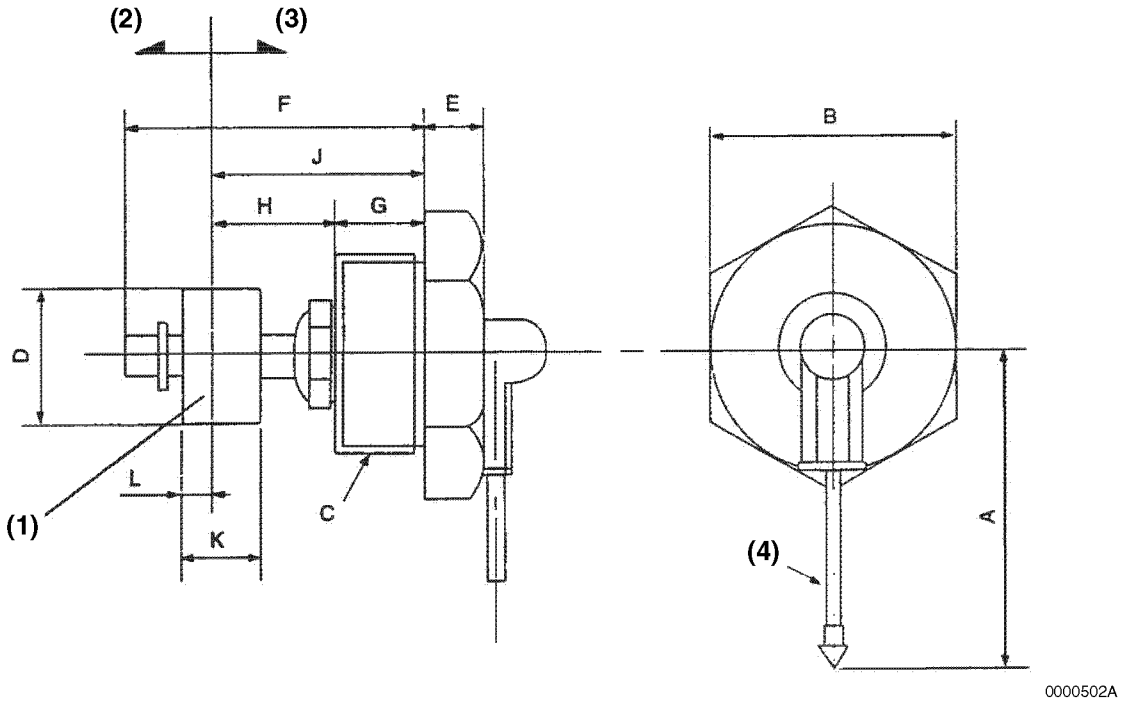
Level Switch for Closed Cooling System Tank

This coolant level switch detects the quantity of coolant in the coolant tank (heat exchanger). It is activated when the coolant quantity falls below a certain level. It turns on the warning lamp and sounds the audible alarm to alert the operator (the new B-type instrument panel does not have this warning device). The coolant level switch is installed on the top of the coolant tank (heat exchanger).

Specifications

Rated Capacity	DC 12V, 3.4 W (Lamp Load)
Operating Voltage	DC 8 - 16V
Operating Temperature Range	-20 - +120°C -4 - +248°F
Cooling Water	Engine Coolant
Yanmar Part Number	127695-91220

Dimensions



1 – Float
2 – ON
3 – OFF
4 – Wire Harness

Figure 6-44

A (mm)	B (mm)	C	D (mm)	E (mm)	F (mm)	G (mm)	H (mm)	J (mm)	K (mm)	L (mm)
60	46	M36 x P1.5	ϕ25	10	55.5	16	23	39 ± 4	15	6

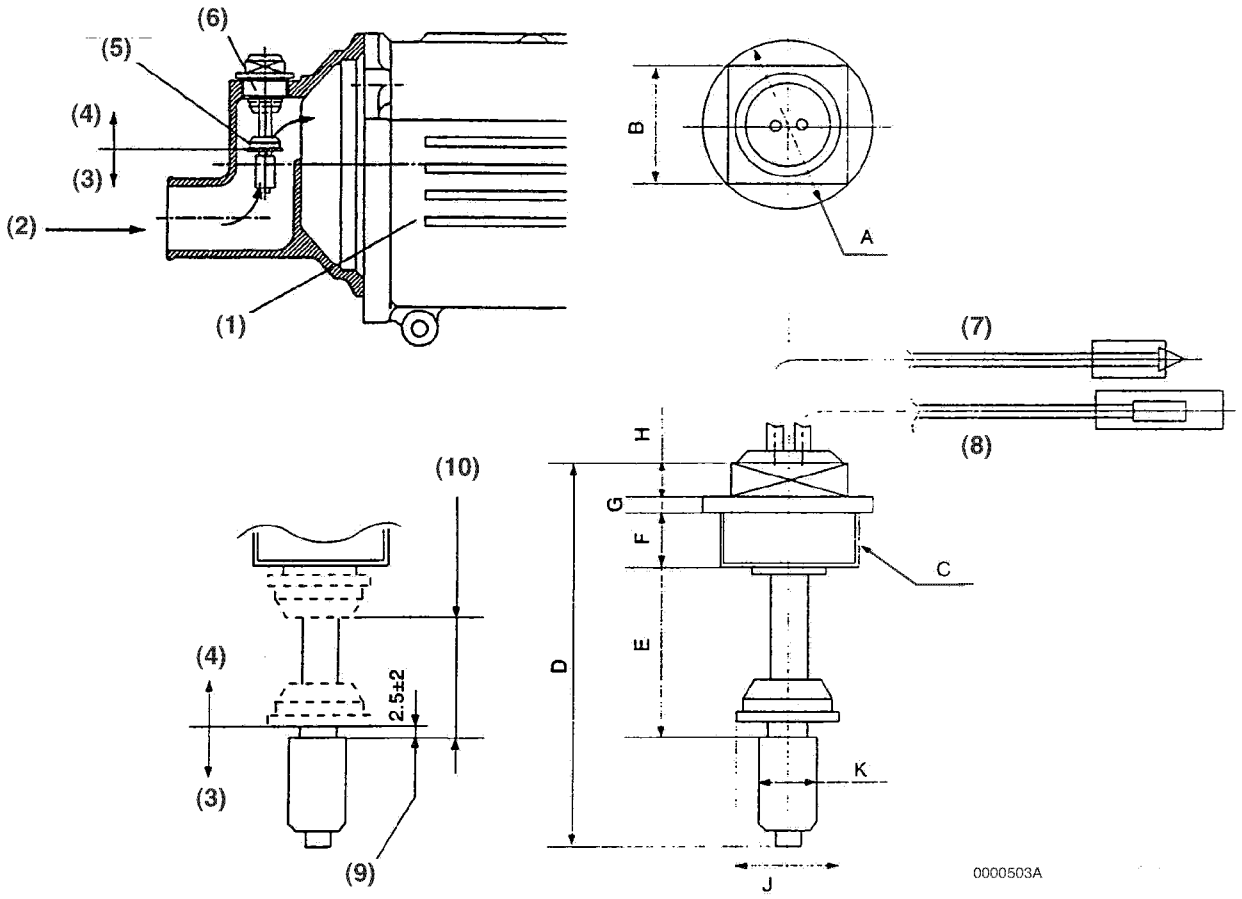
Water Level Switch for Seawater Cooling System

The switch is installed on the intercooler. It monitors the water flow of the seawater coolant and is activated if the coolant flow stops during engine operation. It turns the warning lamp on and sounds the audible alarm to warn the operator.

Specifications

Type	Lead Switch (Earth Float Type)
Rated Capacity	DC 12V, 3.4W (Lamp Load)
Yanmar Part Number	119773-91420

Dimensions



1 – Air Cooler
2 – Seawater In
3 – Switch ON
4 – Switch OFF
5 – Float
6 – Seawater Flow Switch
7 – AV 0.85 Blue/Yellow
8 – AV 0.85 Black
9 – Switching Range
10 – 24, Float Stroke

Figure 6-45

A (mm)	B (mm)	C	D (mm)	E (mm)	F (mm)	G (mm)	H (mm)	J (mm)	K (mm)
ϕ32	22	M26 x P1.5	74.5	32	10	3	7	ϕ19	ϕ11

Note: Tightening torque of M26 thread: 660 kgf-cm (64.7 N·m) (48 ft-lb)

Intake Boost Pressure Switch

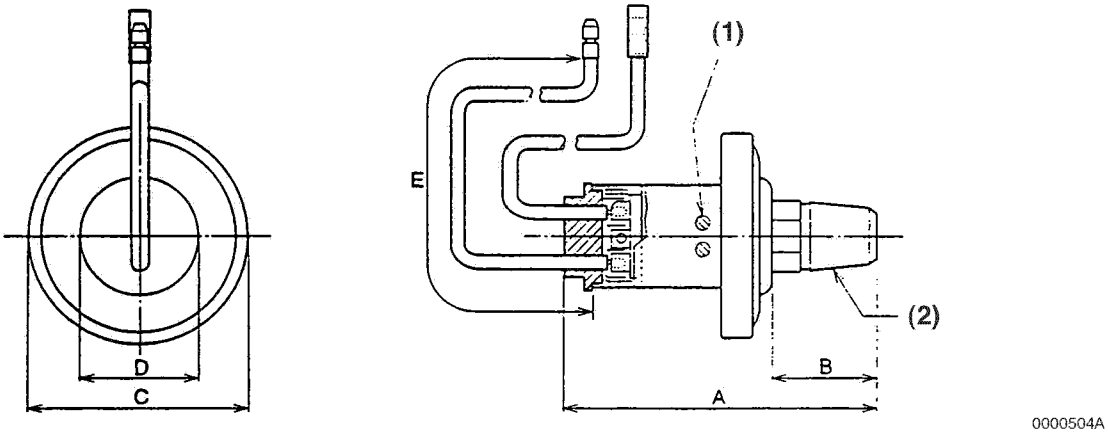
Note: This information is for reference only. The intake boost pressure switch has been discontinued for current production models.

The wastegate valve regulates the intake pressure of the turbocharger to raise combustion efficiency. If the wastegate valve fails, the intake pressure will rise and the turbocharger will be damaged. The boost pressure switch monitors the intake pressure and when the pressure exceeds a specified level, it turns on the warning lamp and sounds the audible alarm to warn the operator.

Specifications

Type	LPLHA	LY2
Rated Capacity	DC 12V, 6A	
Operating Pressure	2.4 - 2.8 kgf/cm² (34.1 - 39.8 psi)	2.65 - 3.05 kgf/cm² (37.7 - 43.4 psi)
Operating Temperature Range	-40 - +120°C -40 - +248°F	
Identification Color	Blue	Yellow
Yanmar Part Number	119773-91380	119595-91290

Dimensions



1 – Identification Color **2 – PT 1/8**

Figure 6-46

A	B	C	D	E	ID Color
61.3 mm	17 mm	42.7 mm	25.5 mm	20 mm	Blue

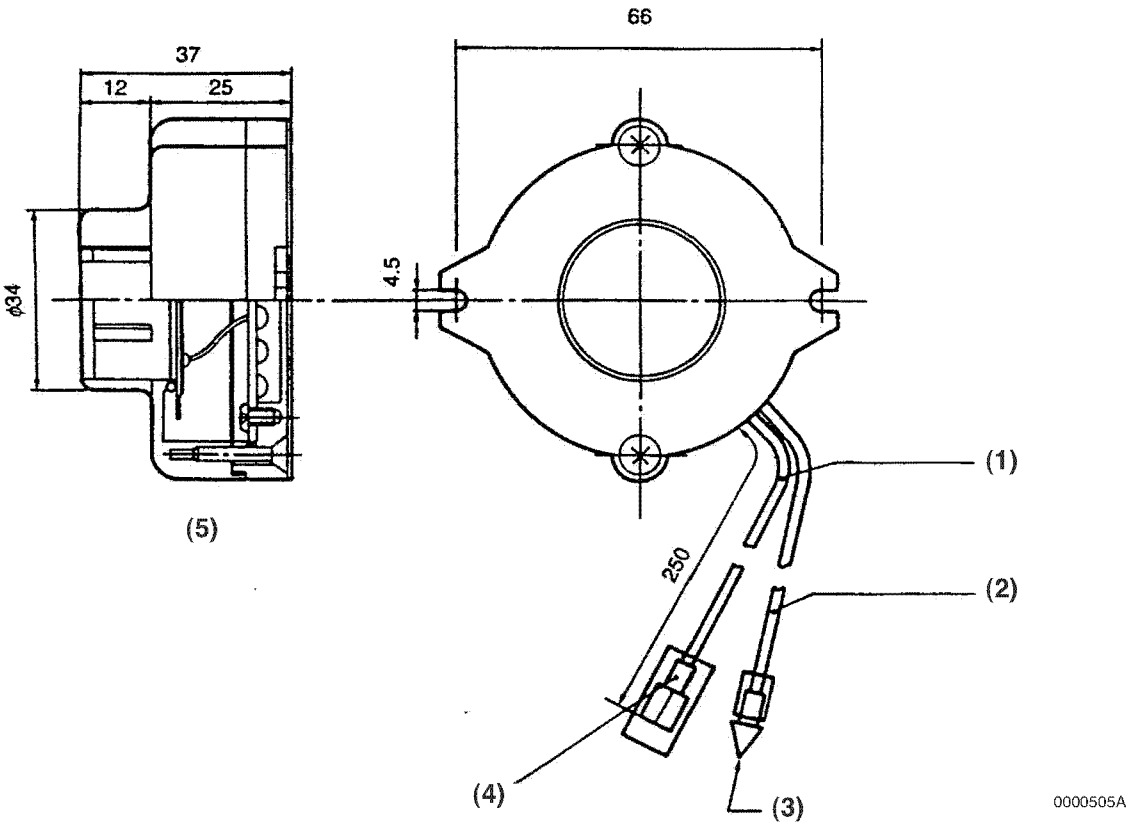
Audible Alarm

An audible alarm (buzzer) is included in the same package as the C, D, and E-type instrument panels. Install the alarm near the panel. The alarm is not designed to be installed on the instrument panel.

Installation:

1. Install the alarm in a place that is well-protected from rain and seawater. The rear of the alarm is not waterproof.
2. Select a position with the least amount of hull vibration.
3. Connect the two wires of the panel (black/white and black/red wires) with the wires of the alarm.

Dimensions



1 – Lead Wire (-) White/Black
2 – Lead Wire (+) Red/Black
3 – Spigot Terminal (+)
4 – Socket Terminal (-)
5 – Rated Voltage: DC 12V

Figure 6-47

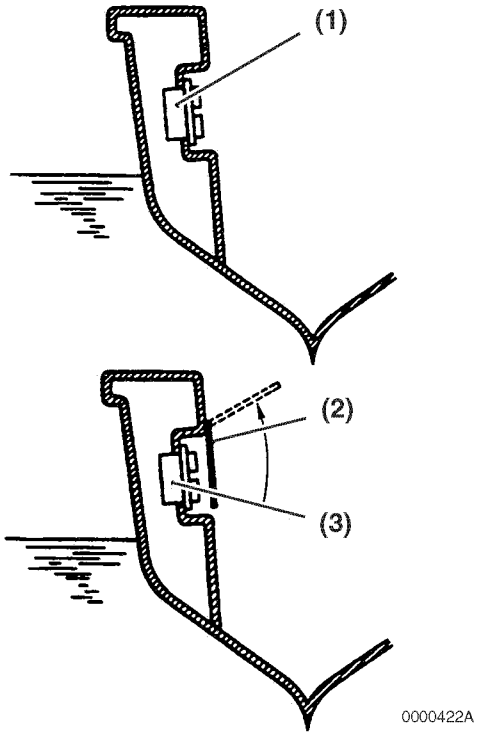
INSTRUMENT PANEL

Panels provide critical information to the operator.

Proper Positioning of the Instrument Panel

Locate panel in a protected area. Install the instrument panel in the cabin if possible. If it must be installed outside, consider the following precautions:

1. Install in a location where there is no danger of the panel being splashed by seawater or rain.
2. If the instrument panel must be installed where it may be splashed by seawater, install it in a recessed position and add a cover **(Figure 6-48)**.
3. Install the instrument panel in a place with little vibration.



1 – Instrument Panel
2 – Transparent Cover
3 – Instrument Panel

Figure 6-48

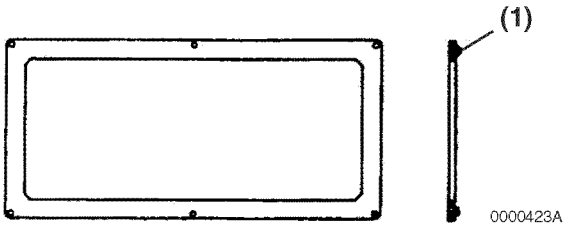
Determining the Angle of the Instrument Panel

Since the gauges on the instrument panel work within a fixed range of the installation angle, ensure that the panel is attached at a permissible angle.

Note: Allowable angle: within 45 - 75° (Instrument panel manufactured by Yanmar)

Procedures for Installing the Instrument Panel

1. Drill the mounting holes in accordance with the instrument panel mounting hole.
2. The instrument panel comes with packing. When attaching the instrument panel outside the cabin, apply an auxiliary packing agent to the packing to protect the rear terminal of the panel. Point the extruded parts toward the hull.



1 – Hull Side

Figure 6-49

Precautions When Installing Instruments

IMPORTANT

When you install instrument panels:

- *Avoid wet locations*
- *Avoid locations subject to vibration*
- *Set meters at correct angle*

Failure to follow these instructions may cause inaccurate or unreliable instrumentation.

1. Avoid places where rain or seawater are expected.
2. Select a position with the least amount of vibration.
3. The angle of the meter is 45 - 75° to the horizontal plane. **(Figure 6-50)**
4. Install at the specified angle to avoid errors on the meters.

Allowable Installation

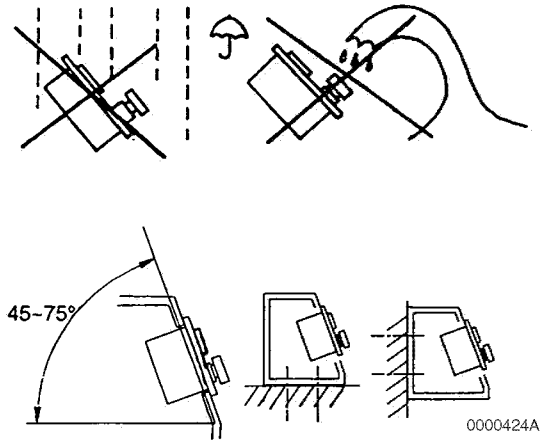


Figure 6-50

Wiring

- Provide suitable cover to protect the lead wire from friction damage and attach it firmly to the bulkhead, etc.
- When connecting the lead wire, make sure that water cannot pass along the wire to the electrical equipment.
- Route the cable so that it does not come in contact with the sharp edges of the engine or with heated areas.

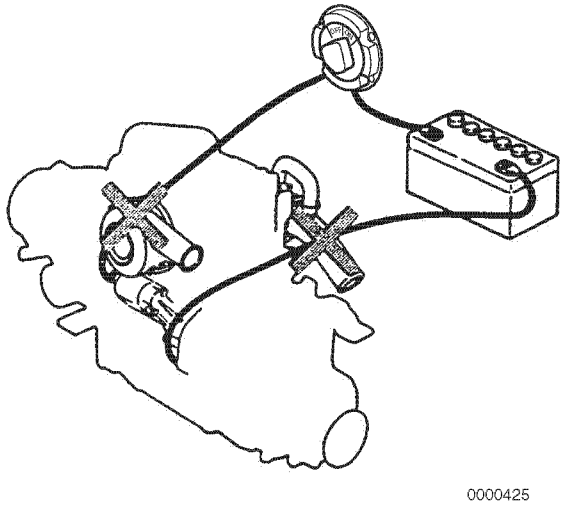


Figure 6-51

- Do not clamp the cables together with the fuel lines. Keep them away from the fuel lines as much as possible.

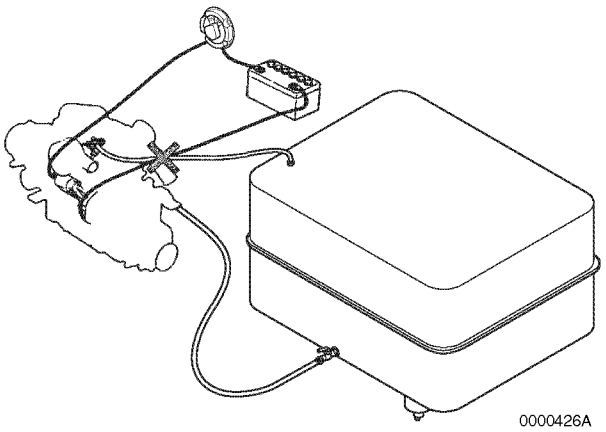


Figure 6-52

- Use wire of the correct size. Wire the panel according to the wiring diagram for each model.

Extension Wire Harness

⚠ WARNING

FIRE HAZARD!

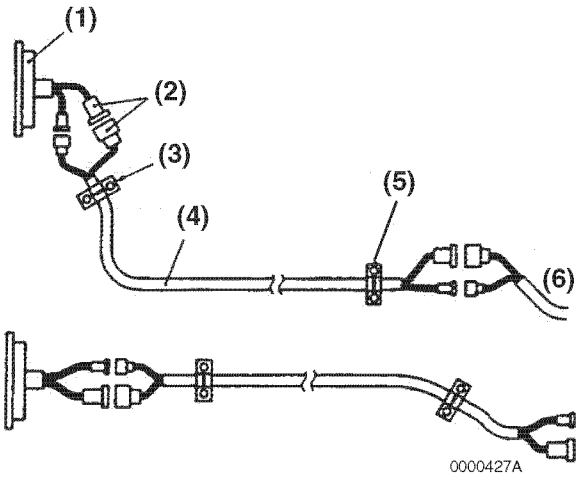
- **Undersized wiring systems can cause an electrical fire.**
- **Failure to comply could result in death or serious injury.**

0000027en

Note: Limit the length of the extension wire harness to 6 m (19.5 ft). For engine models without a starter relay, connect to the starter switch.

If an extension wire harness of more than 6 m (19.5 ft) is directly connected without using a starter relay, starting failure can result due to a voltage drop.

1. Connect the wiring of the instrument panel and engine side to each coupler. Wiring between the engine installation position and the instrument panel is made by the extension wire harness (optional).
   (a) The length of extension of the wire harness varies depending on engine models. For details, refer to the specific engine model options in Volumes 2 and 3.
   (b) The voltage will decrease excessively if the extension harness is longer than the specified length. This leads to engine starting failure and malfunction of the instrument panel gauges. The specified harness length differs depending on the engine model.
   (c) It is impossible to interchange new and old harnesses.
   (d) The old type instrument panels are supplied with a wire harness equipped with both the new and old connectors.
2. **Dual station instrument panel** - When installing the dual station instrument panel, use the correct wire harness for the dual instrument panel option. The dual instrument panel is not available for some engine models.
3. Up to two extension wire harnesses may be connected and used, but do not connect more than two.
4. **Attaching the extension wire harness** - The instrument panel and engine side terminal are connected with an extension wire harness. A coupler is provided at each connection. Be sure to clamp the wire harness near the couplers at both ends (instrument panel and engine side couplers). Take special care to prevent the coupler connected to the instrument panel side from falling out under the weight of the extension wire harness.

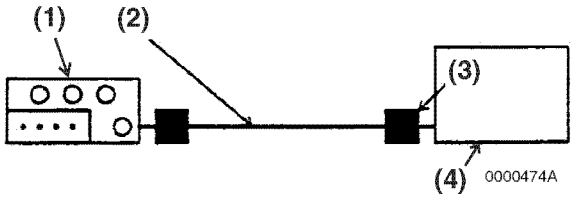


1 – Instrument Panel
2 – Coupler
3 – Clamp
4 – Extension Wire Harness
5 – Clamp
6 – Engine Side

Figure 6-53

Layout of New Extension Wire Harness

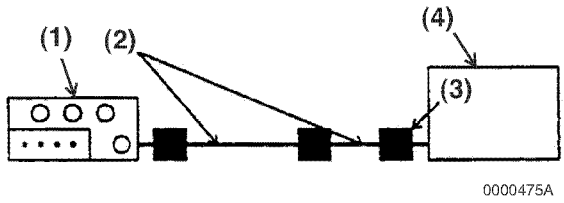
Single Panel, One Extension Wire Harness



1 – New Panel
2 – New Extension Wire Harness
3 – New Connector
4 – Engine

Figure 6-54

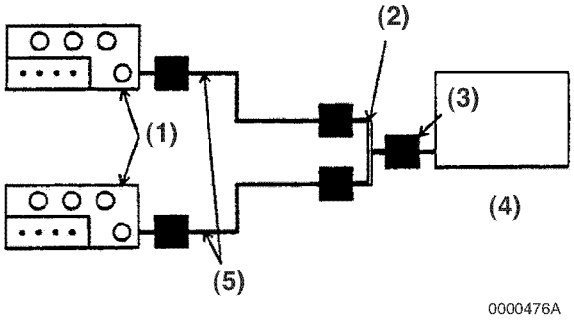
Single Panel, Two Extension Wire Harness



1 – New Panel
2 – New Extension Wire Harness
3 – New Connector
4 – Engine

Figure 6-55

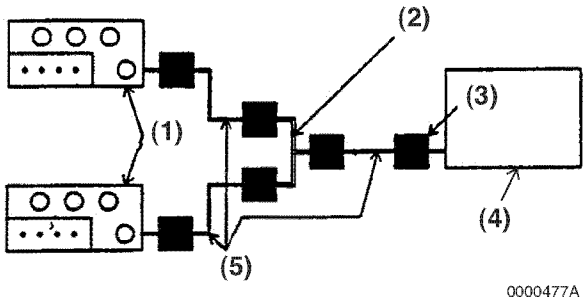
Dual Panel, Two Extension Wire Harness



1 – New Panel
2 – New Connector Wire Harness for Dual Panel
3 – New Connector
4 – Engine
5 – New Extension Wire Harness

Figure 6-56

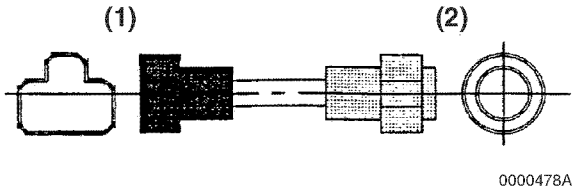
Dual Panel, Three Extension Wire Harness



1 – New Panel
2 – New Connector Wire Harness for Dual Panel
3 – New Connector
4 – Engine
5 – New Extension Wire Harness

Figure 6-57

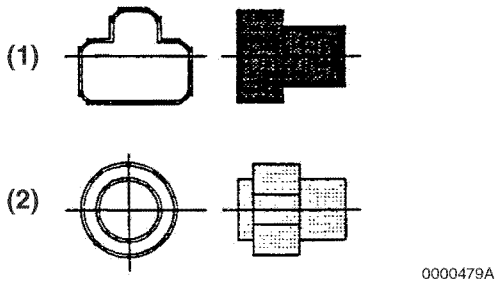
New and Old Connectors



1 – New Connector (Coupler)
2 – Old Connector (Coupler)

Figure 6-58

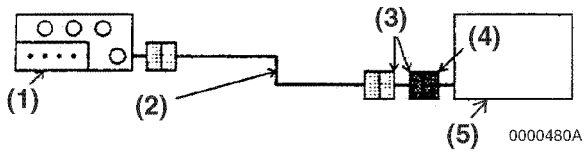
New and Old Extension Wire Harness Layout



1 – Connector (Coupler) of New Extension Wiring Harness
2 – Connector (Coupler) of Old Extension Wiring Harness

Figure 6-59

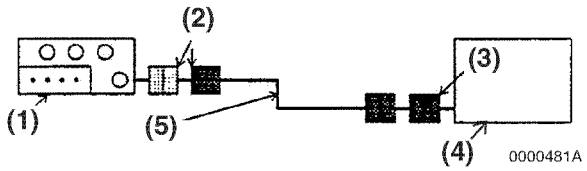
Old Panel, Old Extension Wire Harness with New and Old Connectors



1 – Old Panel
2 – Old Extension Wire Harness
3 – New and Old Connectors
4 – New Connector
5 – Engine

Figure 6-60

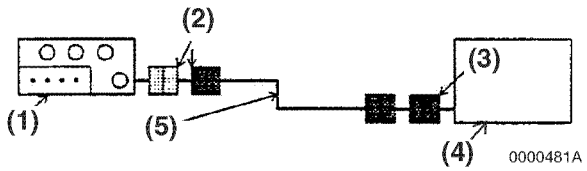
Old Panel, New Extension Wire Harness with New and Old Connectors



1 – Old Panel
2 – New and Old Connectors
3 – New Connector
4 – Engine
5 – New Extension Wire Harness

Figure 6-61

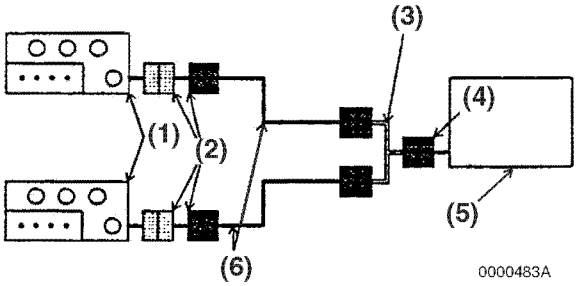
Old Dual Panel, Old Two Extension Wire Harness with New and Old Connectors



1 – Old Panel
2 – New Connector Wire Harness for Dual Panel
3 – New Connector
4 – Engine
5 – New and Old Connectors

Figure 6-62

Old Dual Panel, New Two Extension Wire Harness with New and Old Connectors

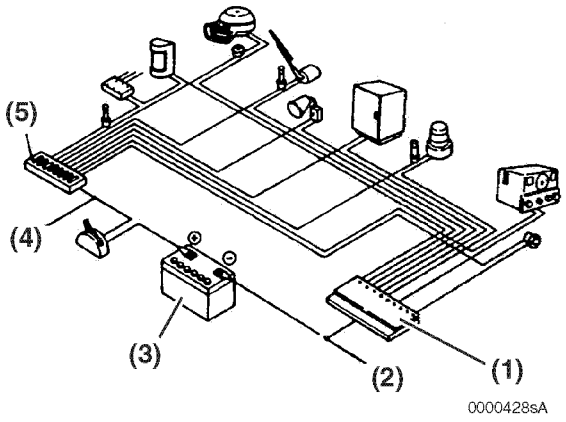


1 – Old Panels
2 – New and Old Connectors
3 – Old Connector Wire Harness for Dual Panel
4 – New Connector
5 – Engine
6 – New Extension Wire Harness

Figure 6-63

Wiring for Drawing Additional Electricity

When drawing additional electricity to power a radio, fan, light, pump, wireless, or other electrical apparatus used in the boat, connect these loads to the positive (+) terminal of the battery by way of the main switch.



1 – Terminal Board
2 – Ground Terminal
3 – Battery
4 – Starting Motor
5 – Fuse

Figure 6-64

Functions by Instrument Panel

Function \ Type of Instrument Panel	A type		B-type	B2 type				C type				D type		E/E1 type		
	A-1	A-2		B2-1	B2-2	B2-3	B2-4	C-1	C-2	C-3	C-4	D-1	D-2	E-1	E-2	E-3
① Switch unit.																
1-1. Key switch for ON/OFF power source. (2-positon switch)	○	○	○	×	×	×	×	×	×	×	×	×	×	×	×	×
1-2. Key switch for GLOW/OFF/ ON/START. (4-positon switch)	×	×	×	○	○	○	○	○	○	○	○	○	○	○	○	○
1-3. Push button switch for engine start.	○	○	○	×	×	×	×	×	×	×	×	×	×	×	×	×
1-4. Push button switch for engine stop.	×	×	×	○	○	○	○	○	○	○	○	○	○	○	○	○
1-5. Illumination switch for meters & alarm lamps.	×	×	○	○	○	○	○	○	○	○	○	○	○	○	○	○
1-6. Buzzer stop switch.	×	×	×	×	×	×	×	○	○	○	○	○	○	○	○	○
② Alarm buzzer.	○	○	○	○	○	○	○	●	●	●	●	●	●	●	●	●
• Cooling water high temp.	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
• Lube oil low pressure.	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
• * Sail drive seal leak.	○	○	○	○	○	×	○	○	○	×	○	×	×	×	×	×
• * Lube oil low pressure for marine gear.	×	×	×	×	×	○	×	×	×	○	×	×	○	×	×	○
③ Alarm lamp unit.																
• Battery not charging.	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
• Cooling water high temp.	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
• Lube oil low pressure.	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
• * Sail drive seal leak.	×	○	○	○	○	×	○	○	○	×	○	×	×	×	×	×
• * Lube oil low pressure for marine gear.	×	×	×	×	×	○	×	×	×	○	×	×	○	×	×	○
• * Lube oil filter clogged.	×	×	×	×	×	○	×	×	×	○	×	×	○	×	×	○
• * Fuel oil water separator (Water level).	×	×	×	×	×	×	×	×	×	×	×	×	×	×	○	×
④ Tachometer																
• Tachometer I.D. No. P=97			○	×	×	×	×	×	×	×	×	×	×	×	×	×
• Tachometer I.D. No. P=114			×	○	×	×	×	×	×	×	×	×	×	×	×	×
• Tachometer I.D. No. P=116			×	×	×	×	○	×	×	×	○	×	×	×	×	×
• Tachometer I.D. No. P=127			×	×	○	×	×	×	○	×	×	○	×	×	○	×
• Tachometer I.D. No. P=129			×	×	×	○	×	×	×	○	×	×	×	○	×	×
⑤ Meters.																
• Lube oil pressure meter.								○	○	○	○	○	○	○	○	○
• Cooling water temp. meter.								○	○	○	○	○	○	○	○	○
• Boost meter (Turbo).								×	×	×	×	×	○	×	○	○
5-1. Operation hour meter.								○	○	○	○	○	○	○	○	○
⑥ Other.																
6-1. Quartz clock.								×	×	×	×	○	○	○	○	○
6-2. Fuse box.								○	○	○	○	○	○	○	○	○

0003880

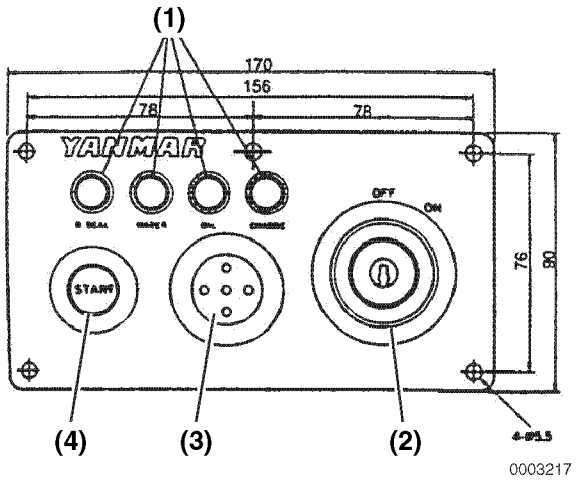
Note: 1. O = Equipped on panel. X = Not equipped on panel. ●= Installed by boatbuilder
2. Depending on the instrument panel type, the asterisk (*) functions may not be activated because the corresponding sensors are not installed on the engine.

Internal Yanmar Code

Type of Panel	ID Number
Panel	Yanmar Part No.
A1	D28270-91101
A2	D28371-91100
B	D28170-91110
B2-1	29171-91101
B2-2	D24411-92890
B2-3	D27675-91200
B2-4	D29670-91110
C-1	D29171-91201
C-2	D24411-92920
C-3	D27675-91170
C-4	D29171-91180
D1	D24411-92850
D-2	D27675-91300
E-1	D19171-91130
E-2	D19182-91130
E-3	D27675-91100
E-4	D27675-91110

Instrument Panel Configurations

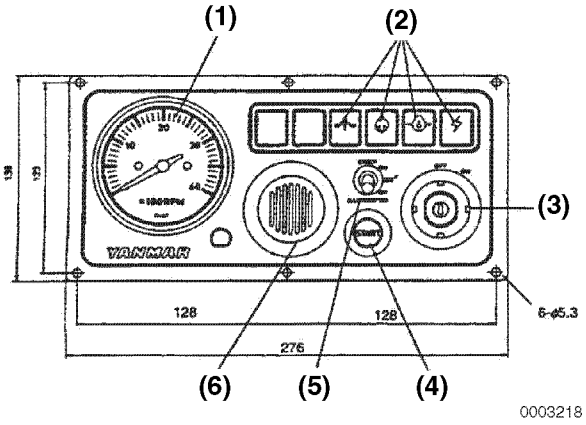
A-Type



1 – Warning Lamps
2 – Key Switch
3 – Alarm Buzzer
4 – Engine Start Push Button

Figure 6-65

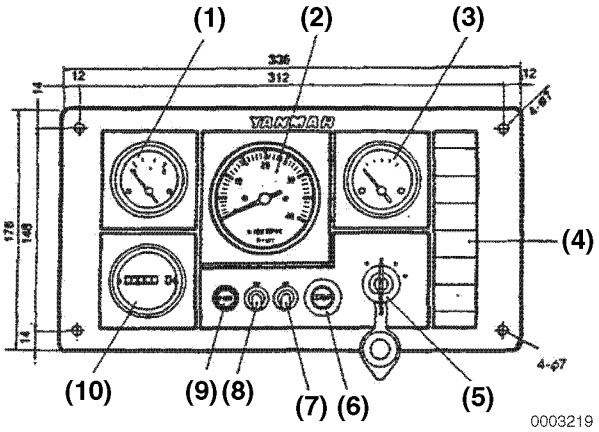
B and B2-Type



1 – Tachometer
2 – Warning Lamps
3 – Key Switch
4 – Engine Start Push Button
5 – Panel Illumination Switch
6 – Alarm Buzzer

Figure 6-66

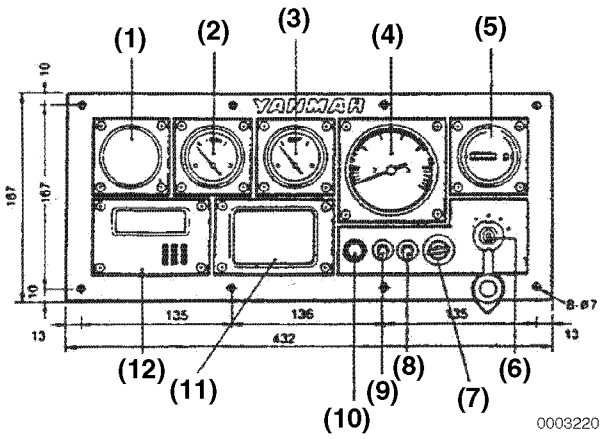
C-Type



1 – Meter
2 – Tachometer
3 – Meter
4 – Warning Lamps
5 – Key Switch
6 – Engine Stop Push Button
7 – Panel Illumination Switch
8 – Buzzer Stop Switch
9 – Fuse Box
10 – Hour Meter

Figure 6-67

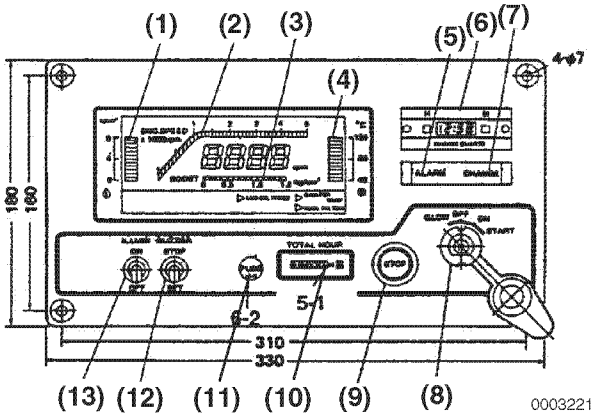
D-Type



1 – Meter
2 – Meter
3 – Meter
4 – Tachometer
5 – Hour Meter
6 – Key Switch
7 – Engine Stop Push Button
8 – Panel Illumination Switch
9 – Buzzer Stop Switch
10 – Fuse Box
11 – Warning Lamp Unit
12 – Quartz Clock

Figure 6-68

E-Type



1 – Meter
2 – Tachometer
3 – Meter
4 – Meter
5 – Warning Lamp
6 – Quartz Clock
7 – Warning Lamp
8 – Key Switch
9 – Engine Stop Push Button
10 – Hour Meter
11 – Fuse Box
12 – Buzzer Stop Switch
13 – Panel Illumination Switch

Figure 6-69

Functions by New Type Instrument Panel

Type of New Instrument Panel	New B											New C									New D						
Functions	B2-N1	B2-N2	B2-N3	B2-N4	B2-N5	B2-N6	B2-N7	B2-N8	B2-N9	B2-N10	B2-N11	C-N1	C-N2	C-N3	C-N4	C-N5	C-N6	C-N7	C-N8	C-N9	D-N1	D-N2	D-N3	D-N4	D-N5	D-N6	D-N7
1. Switch unit																											
1-1. Key Switch for GLOW/OFF/ON/START	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
1-2. Push Button Switch for Engine Stop	X	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
1-3. Alarm Buzzer	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
1-4. Alarm Buzzer Stop Switch	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
1-5. Illumination Switch for Meters	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
1-3. Alarm Buzzer																											
• Cooling Water High Temperature	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
• Lube Oil Low Pressure	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
• *Sail Drive Seal Leak	O	O	O	X	X	O	X	X	X	X	X	O	O	X	X	O	X	X	X	X	X	X	X	X	X	X	X
• *Hydraulic Oil Low Pressure for Marine Gear or Sterndrive Gear Oil Level	X	X	X	O	X	X	X	X	X	X	X	X	X	O	O	X	O	O	O	O	X	O	O	O	O	O	O
• *Fuel Water Separator (Water Level)	X	X	X	X	O	X	X	X	O	X	X	X	O	X	O	X	X	O	X	X	X	X	O	X	X	O	X
• *Seawater Flow	X	X	X	X	O	X	O	X	O	O	X	X	X	O	O	X	X	O	O	X	X	O	O	X	O	O	X
• *Cooling Water Level for Closed Cooling Tank	X	X	X	O	X	X	O	X	X	O	X	X	X	O	O	X	X	O	O	X	X	O	O	X	O	O	X
• *Boost Pressure High	X	X	X	X	O	X	O	O	X	X	X	X	X	O	O	X	O	O	O	O	X	O	O	O	O	O	O
2. Alarm Unit (6-lamp Type)																											
• Battery Not Charging	O	O	O	O	O	O	O	O	O	O	O																
• Cooling Water High Temperature	O	O	O	O	O	O	O	O	O	O	O																
• Lube Oil Low Pressure	O	O	O	O	O	O	O	O	O	O	O																
• *Sail Drive Seal Leak	O	O	O	X	X	O	X	X	X	X	X																
• *Hydraulic Oil Low Pressure for Marine Gear or Sterndrive Gear Oil Level	X	X	X	O	X	X	X	X	X	X	X																
• *Lube Oil Filter Clogged	X	X	X	O	X	X	X	X	X	X	X																
• *Fuel Water Separator (Water Level)	X	X	X	X	O	X	X	X	O	X	X																
• *Seawater Flow	X	X	X	X	O	X	O	X	O	O	X																
• *Cooling Water Level for Closed Cooling Tank	X	X	X	O	X	X	O	X	X	X	X																
• *Boost Pressure High	X	X	X	X	O	X	O	O	X	X	X																
• *Preheat	X	X	X	X	X	X	X	X	O	O	O																

Type of New Instrument Panel	New B											New C									New D						
Functions	B2-N1	B2-N2	B2-N3	B2-N4	B2-N5	B2-N6	B2-N7	B2-N8	B2-N9	B2-N10	B2-N11	C-N1	C-N2	C-N3	C-N4	C-N5	C-N6	C-N7	C-N8	C-N9	D-N1	D-N2	D-N3	D-N4	D-N5	D-N6	D-N7
3. Alarm Unit (10-lamp Type)																											
• Battery Not Charging												O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
• Cooling Water High Temperature												O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
• Lube Oil Low Pressure												O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
• *Sail Drive Seal Leak												O	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X
• *Hydraulic Oil Low Pressure For Marine Gear Or Sterndrive Gear Oil Level												X	X	O	O	X	O	O	O	O	X	O	O	O	O	O	O
• *Lube Oil Filter Clogged												X	X	O	X	X	X	X	O	X	X	O	X	X	O	X	X
• *Fuel Water Separator (Water Level)												X	O	O	O	X	X	O	X	X	X	X	O	X	X	O	X
• *Seawater Flow												X	X	O	O	X	X	O	O	X	X	O	O	X	O	O	X
• *Cooling Water Level For Closed Cooling Tank												X	X	O	O	X	X	O	O	X	X	O	O	X	O	O	X
• *Boost Pressure High												X	X	O	O	X	O	O	O	O	X	O	O	O	O	O	O
• *Preheat												X	X	X	X	X	X	O	O	O	X	X	X	X	O	O	O
4. Tachometer Unit																											
• Tachometer with Hour Meter, I.D. No. P=97	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
• Tachometer with Hour Meter, I.D. No. P=114	X	O	X	X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
• Tachometer with Hour Meter, I.D. No. P=116	X	X	X	X	O	O	X	X	O	X	X	X	X	X	O	O	X	O	X	X	X	X	O	X	X	O	X
• Tachometer with Hour Meter, I.D. No. P=127	X	X	O	X	X	X	X	O	X	X	O	X	O	X	X	X	O	X	X	O	O	X	X	O	X	X	O
• Tachometer with Hour Meter, I.D. No. P=129	X	X	X	O	X	X	O	X	X	O	X	X	X	O	X	X	X	X	O	X	X	O	X	X	O	X	X
5. Sub Meters																											
5-1. Lube Oil Pressure Meter												O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
5-2. Cooling Water Temperature Meter												O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
5-3. Boost Meter (Turbocharger)												X	X	X	X	X	X	X	X	X	X	O	O	O	O	O	O
6. Clock Unit																											
6-1. Quartz Clock												X	X	X	X	X	X	X	X	X	O	O	O	O	O	O	O

* *Varies by engine model. Refer to information for specific engine model in Volume 2 or 3.*

Note: O = Equipped on panel. X = Not equipped on panel.

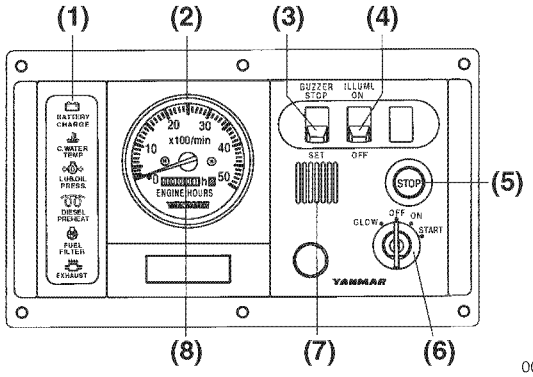
Note: The instrument panel ID Number is specified at the instrument panel frame.

Type of Panel	ID Number
Panel	Yanmar Part No.
B2-N1	128391-91130
B2-N2	129170-91130
B2-N3	129574-91130
B2-N4	119573-91130
B2-N5	119773-91130
B2-N6	129670-91130
B2-N7	119575-91130
B2-N8	119175-91130
B2-N9	119773-91131
B2-N10	119575-91131
B2-N11	119175-91131
C-N1	129170-91161
C-N2	129574-91161
C-N3	127675-91161
C-N4	119773-91160
C-N5	129670-91161
C-N6	119175-91160
C-N7	119773-91162
C-N8	127675-91163
C-N9	119175-91162
D-N1	129574-91191
D-N2	127675-91193
D-N3	119773-91190
D-N4	119175-91190
D-N5	127675-91193
D-N6	119773-91192
D-N7	119175-91192

Instrument Panel Configuration (New-Type Panel)

This is a module-type instrument panel. It consists of the switch unit, warning lamp unit and meter unit. Each module unit can be used separately in a panel frame.

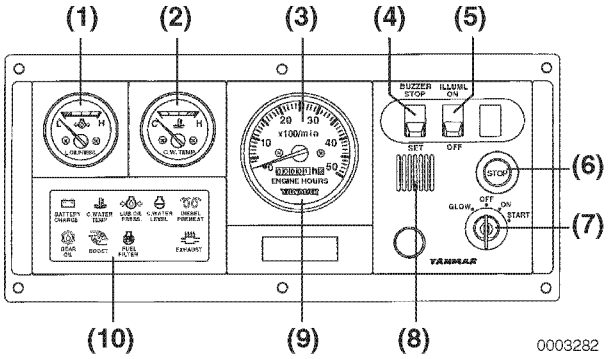
New B-Type



1 – Warning Lamp Unit - 6 Lamp Type
2 – Tachometer
3 – Buzzer Stop Switch
4 – Panel Illumination Switch
5 – Engine Stop Switch
6 – Key Switch
7 – Alarm Buzzer
8 – Hour Meter

Figure 6-70

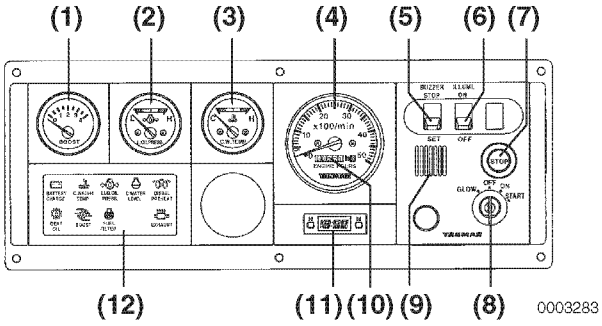
New C-Type



1 – Oil Pressure Meter
2 – CW Temperature Meter
3 – Tachometer
4 – Buzzer Stop Switch
5 – Panel Illumination Switch
6 – Engine Stop Switch
7 – Starter Key Switch
8 – Alarm Buzzer
9 – Hour Meter
10 – Warning Lamp Unit - 10 Lamp Type

Figure 6-71

New D-Type



1 – Turbocharger Boost Pressure Meter
2 – Engine Oil Pressure Meter
3 – CW Temperature Meter
4 – Tachometer
5 – Buzzer Stop Switch
6 – Panel Illumination Switch
7 – Engine Stop Switch
8 – Starter Key Switch
9 – Alarm Buzzer
10 – Hour Meter
11 – Quartz Clock
12 – Warning Lamp Unit - 10 Lamp Type

Figure 6-72

Instrument Panel Parts (New-Type VDO Panel)

New Type B (VDO) - 3JH4E/4JH4E and 3YM30/3YM20/2YM15

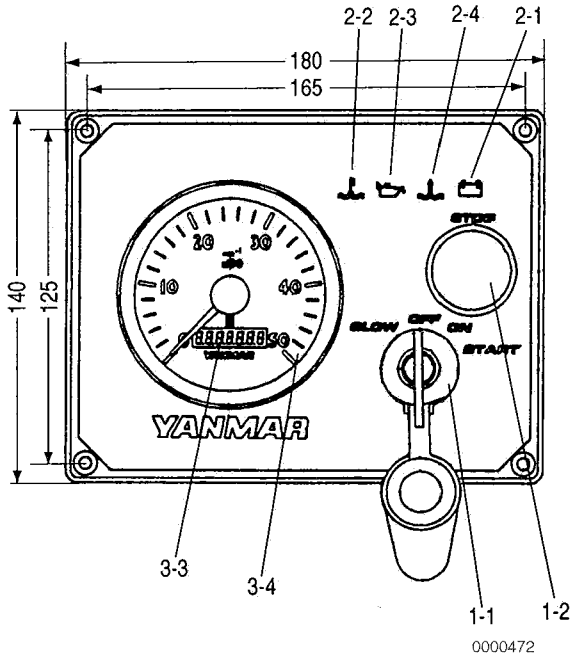


Figure 6-73

New Type C (VDO) - 3JH4E/4JH4E

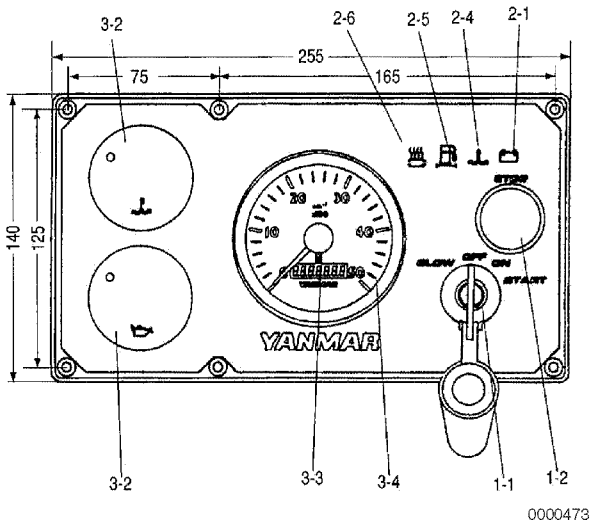


Figure 6-74

Switch Unit	Warning Lamp Unit	Meters
1-1. Key switch for GLOW / OFF / ON / START (4-position switch)	2-1. Battery Low Charge Alarm	3-1. Engine Oil Pressure Gauge
1-2. Engine Stop Button	2-2. Coolant High Temperature Alarm	3-2. Coolant Temperature Gauge
	2-3. Engine Oil Low Pressure	3-3. Hour Meter
	2-4. Water In Sail Drive Seal Warning Lamp	3-4.Tachometer
	2-5. Water In Fuel Filter Warning Lamp	
	2-6. Seawater Insufficient Flow Alarm	

Functions by 3JH4E/4JH4E and 3YM30/3YM20-Type Instrument Panels

Type of Instrument Panel	New Type B (VDO) for 3JH4E/4JH4E and 3YM30/3YM20/2YM15	New Type C (VDO) for 3JH4E/4JH43
Function		
1. Switch Unit		
1-1 Key Switch for GLOW/OFF/ON/START (4-position switch)	O	O
1-2 Engine Stop Switch	O	O
2. Warning Lamp Unit		
2-1 Battery Low Charge Warning	O	O
2-2 Cooling Water High Temperature Warning	O	X
2-3 Engine Oil Low Pressure Warning	O	X
2-4 Water in Sail Drive Seal Warning	O	O
2-5 Water in Fuel Filter Warning	X	O
2-6 Low Cooling Seawater Flow Warning	X	O
3. Meters (Gauges)		
3-1 Engine Oil Pressure Gauge	X	O
3-2 Coolant Temperature Gauge	X	O
3-3 Hour Meter	O	O
3-4 Tachometer	O	O

Note: O = Equipped on panel. X = Not equipped on panel.

Type of Panel	Yanmar Part No.
New Type B (VDO) for 3JH4E/4JH4E and 3YM30/3YM20/2YM15	129271-91110
New Type C (VDO) for 3JH4E/4JH43	129271-91160

Configuration and Function of TELEFLEX Switch Panel and Digital Display

Engine Model: 6LY3-ETP

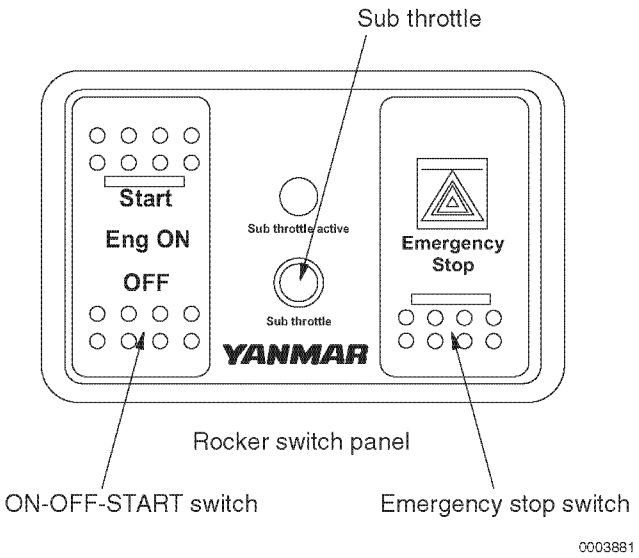


Figure 6-75

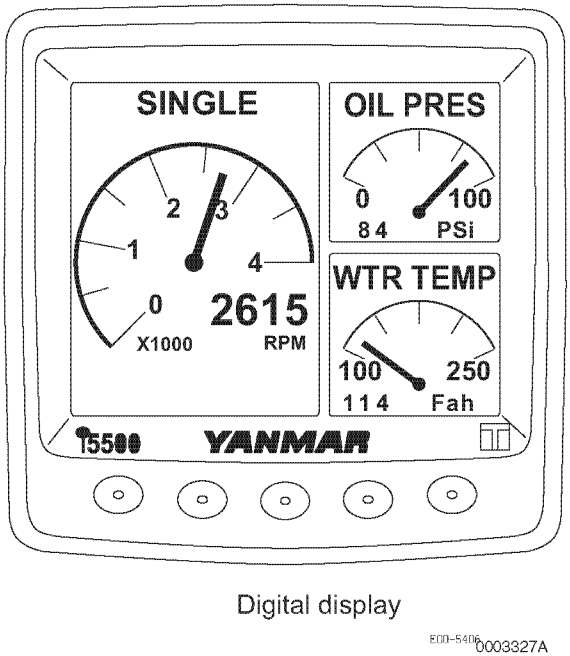


Figure 6-76

	Type of Instrument Panel	Digital Display	Rocker Switch Panel
	Function		
1 - Switch Unit			
	ON-OFF-START Switch	X	O
	Emergency Stop Switch	X	O
2 - Alarm Unit			
	Alarm Information	O	X
	Sub Throttle Lamp	X	O
3 - Meters			
	Tachometer	O	X
	Engine Oil Pressure	O	X
	Others*	O	X
4 - Sub Throttle		X	O

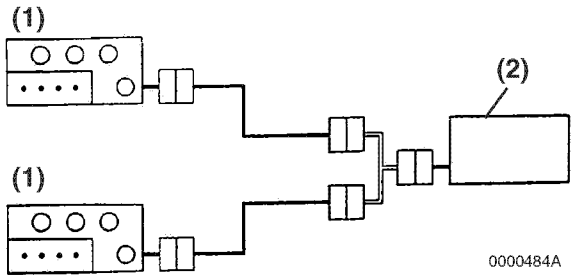
Note O = Equipped on panel. X = Not equipped on panel.

*Coolant Temperature; Engine Oil Temperature; Fuel Temperature; Boost Pressure; Voltage; Load Factor; Throttle Value; Fuel Consumption Rate; Gear Shift (F/N/R)

Combination of Dual Instrument Panels

Instrument panel combinations differ depending on the engine model. Please refer to the specific engine model information in Volume 2 or 3.

	New Type Panel	Old Type Panel	New/Old Mixed
Panel Type	B X B	B2 X B2	B2 X New B
	B X C	B2 X C	B2 X New C
	B X D	B2 X D	B2 X New D
	C X C	E1 X E	
	C X D		

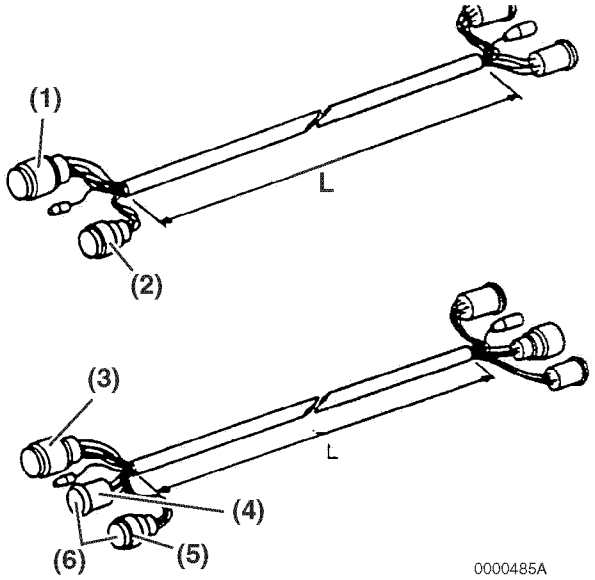


1 – Panel **2 – Engine**

Figure 6-77

Length of Extension Wire Harness (Old and New Type)

Type	Name	L (m)	Yanmar Part Number (Old Type Code)
EWN3	Extension wire harness, 3 m	2.75 - 2.85	D28391-94500 2-connector type (D28170-91500)
EWN4	Extension wire harness, 4 m	3.75 - 3.85	D29574-91510 3-connector type (D24611-77840)
EWN6	Extension wire harness, 6 m	5.75 - 5.85	D29574-91520 3-connector type (D19171-91501)

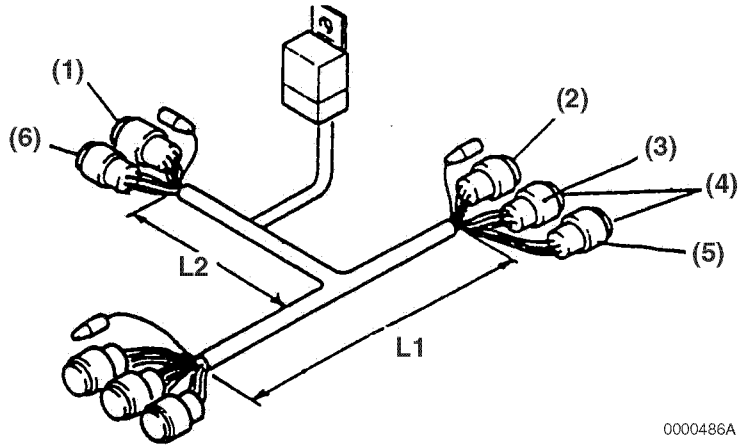


1 – (8P, Connector, New Type)
6P, Connector
2 – 4P, Connector (3P, Connector, New Type)
3 – 8P, Connector, New Type)
6P, Connector
4 – (3P, Connector, New Type)
5 – (8P, Connector, New Type)
6 – 4P, Connector

Figure 6-78

Extension Wire Harness for Dual Instrument Panel

Type	L1 (Old Type)	L2 (Old Type)	Yanmar Part Number (Old Type Code)
CWN1	370 mm (340 mm)	200 mm (200 mm)	D29574-91590 (D19171-91590)

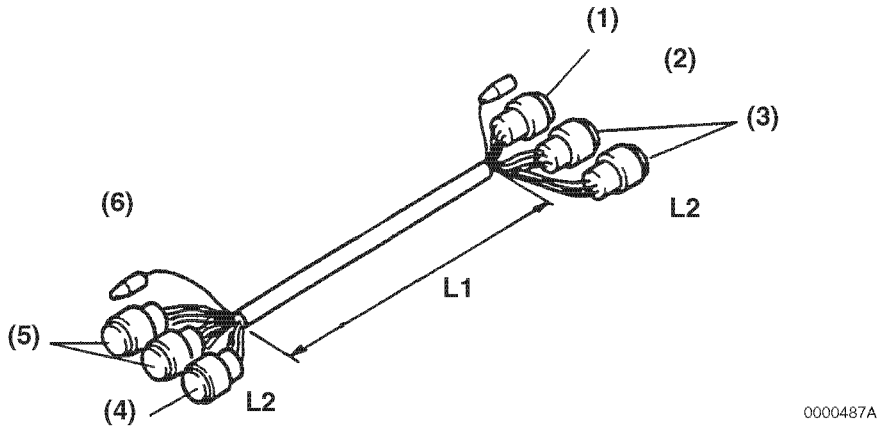


1 – (8P, Connector, New Type) 6P, Connector
2 – 8P, Connector, New Type) 6P, Connector
3 – (3P, Connector, New Type)
4 – 4P, Connector
5 – (8P, Connector, New Type)
6 – 4P, Connector (3P, Connector New Type)

Figure 6-79

New and Old Connectors

L1	L2	Yanmar Part Number
100 mm	100 mm	129574-77860



1 – 6P, Connector
2 – Old Type, Connector
3 – 4P, Connector
4 – 3P, Connector
5 – 8P, Connector
6 – New Type Connector

Figure 6-80

COLD STARTING AID

An air heater or glow plug may be available for warming intake air during starting in low temperatures. The air heater is mounted between the intake manifold and intake manifold coupling.

The device may be automatic or may activated by a preheat switch. See the Operators Manual or Service manual of your equipment for specifics.

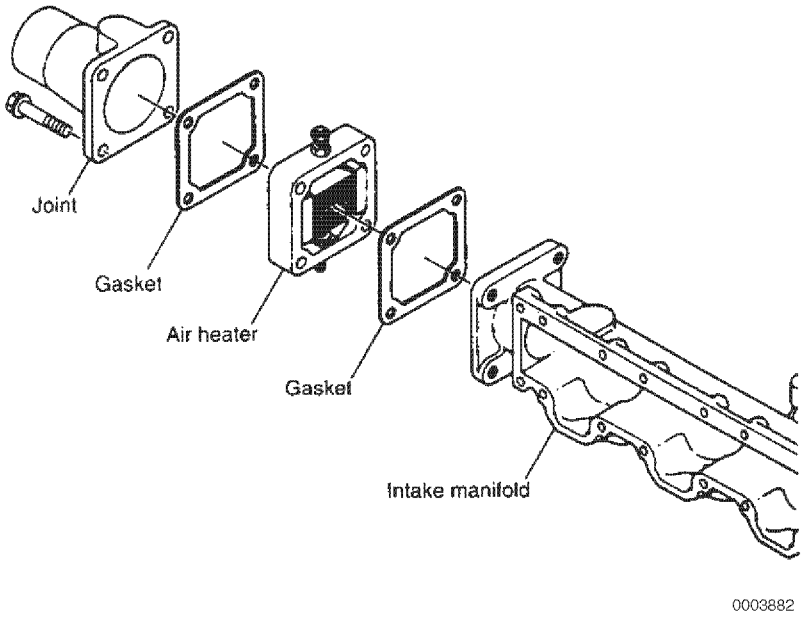


Figure 6-81

Air Heater

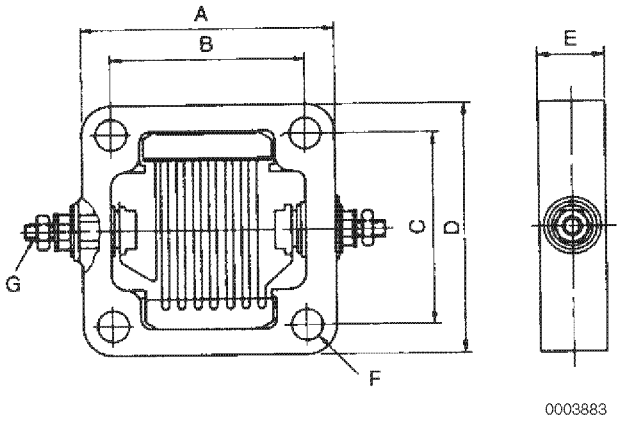


Figure 6-82

Specifications

Type	Unit	AH 1	AH 2	AH 3
Yanmar Part Number		129100-77500	119005-77050	127695-77500
Rated Output	W	400	500	500 (2000)
Rated Current	A	35	42	42 (90)
Rated Voltage	V	12		12 (24)
Rated Operation Interval	Seconds	ON: 60 OFF: 30		
Dimensions				
A	mm (in.)	78 (3.07)	88 (3.47)	178 (7.00)
B	mm (in.)	60 (2.36)	70 (2.76)	80 + 80 (3.15 + 3.15)
C	mm (in.)	60 (2.36)	70 (2.76)	90 (3.54)
D	mm (in.)	78 (3.07)	88 (3.47)	108 (4.25)
E	mm (in.)	18 (0.71)	18 (0.71)	20 (0.79)
F	mm	4 x ϕ9	4 x ϕ9	4 x ϕ9
G (Thread Size)	mm	M6 x P1		

Glow Plug

The glow plug heats the areas around the combustion chamber to make the engine starting easier. The plug is installed in the cylinder head or intake manifold. The number of plugs varies depending on the engine model.

Specifications

Rated Voltage	DC 12V
Rated Current	A
Yanmar Part Number	119775-77600

Dimensions

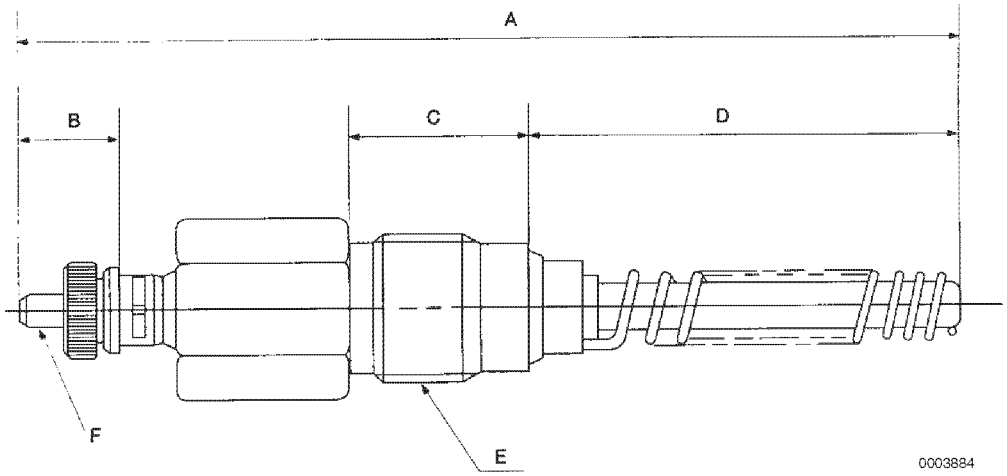


Figure 6-83

Type	A	B	C	D	E	F
AG 1	115 mm	12 mm	22 mm	53 mm	M18 x P 1.5	M4 x P0.7

Note: Tightening torque:
M18: 3 - 4 kgf-m (29.4 - 39.2 N·m) (21.6 - 28.9 ft-lb)
M4 Nut: 0.1 - 0.15 kgf-m (0.98 - 1.47 N·m) (8.7 - 13.0 in.-lb)

Heater Plug

Note: Production start end of September, 1999.

Besides the conventional function of heating intake air for easy starting, the function of reducing exhaust (bluish white smoke), which is emitted soon after starting in cold areas, has also been added.

Specifically, the heater function as described below was added to the conventional starting operation of turning the key switch manually to GLOW to start the heater and starter motor.

Note: Low cetane number diesel fuels cause the engine to emit more bluish white smoke. We recommend the use of diesel fuels with a minimum cetane number of 45.

Operation of Cold Starting Aid

The heater starts with the key switch on GLOW, turning key switch OFF turns off the heater. Turning the key switch ON will cause the heater to start and the preheat lamp to go on. The heater stays turned off when cooling water temperature exceeds 42°C (108°F), and the preheat lamp will also remain off. Turning the key switch to the START position (engine starts), the preheat lamp goes out and heater continues to work even after releasing the key switch to the ON position. The heater, however, will automatically turn off within 3 minutes maximum or when cooling water temperature reaches 42°C (108°F), whichever happens first.

Except for key operation, all operations of the preheat lamp and heater are automatically controlled by the timer.

Note: To reduce bluish white smoke during engine starting (if preheat lamp goes on when the key switch is turned to the ON position), hold the key in the ON position until preheat lamp goes out.

Operation of Key Switch	Operation Timing	
	Heater Plug	Preheat Lamp
GLOW	ON	OFF
OFF	OFF	OFF
ON	ON (maximum 30 seconds or engine cooling water temperature reaches 42°C)	ON (when key turned from OFF to ON). Alarm buzzer not activated.
START	ON (3 minutes or until engine cooling water temperature reaches 42°C)	OFF
ON (engine running)		OFF

Specifications

Rating	11 V 58 A
Used Heater Plug	2 pieces/engine
Install Thread Diameter	M20 x P1.5
Tightening Torque	1.5 kgf-m (14.7 N·m) (130 in.-lb)

Note: Engines with new cold starting aid system have large heater capacity. Accordingly, install a large capacity battery.

Dimensions

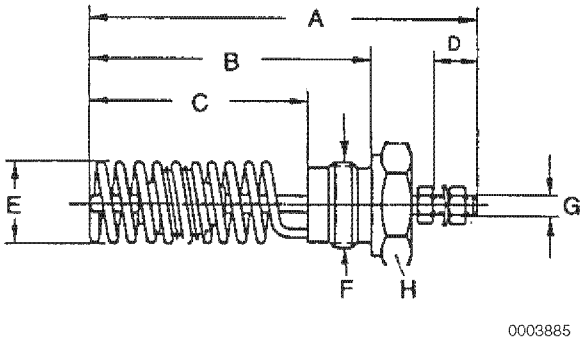


Figure 6-84

Type	A	B	C	D	E	F	G	H
AG 2	89 mm	65 mm	50 mm	10 mm	18 mm	M20 x P1.5	M5	26 mm
Yanmar Part Number	119575-77050							

Cooling Water Temperature Switch

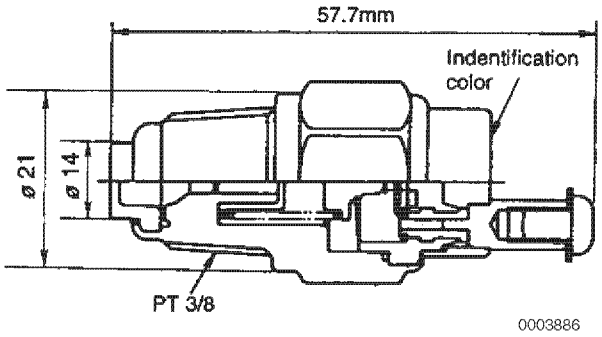


Figure 6-85

Specifications

Operating Temperature	ON	40 - 44°C 104 - 110°F
	OFF	33 - 37°C 91 - 99°F
Rated Capacity		DC 12V, 1A
Response Time		Within 60 seconds
Operating Temperature Range		-97 - 130°C -143 - 266°F
Identification Color		Orange
Applicable Engine Type		Heater Plug Type for Cold Starting Aid (optional)
Yanmar Part Number		124616-01370

Note: Tightening torque of PT 3/8 thread:
240 - 320 kgf-cm (23.5 - 31.4 N·m)
(208 - 278 in.-lb)

REMOTE CONTROL SYSTEM

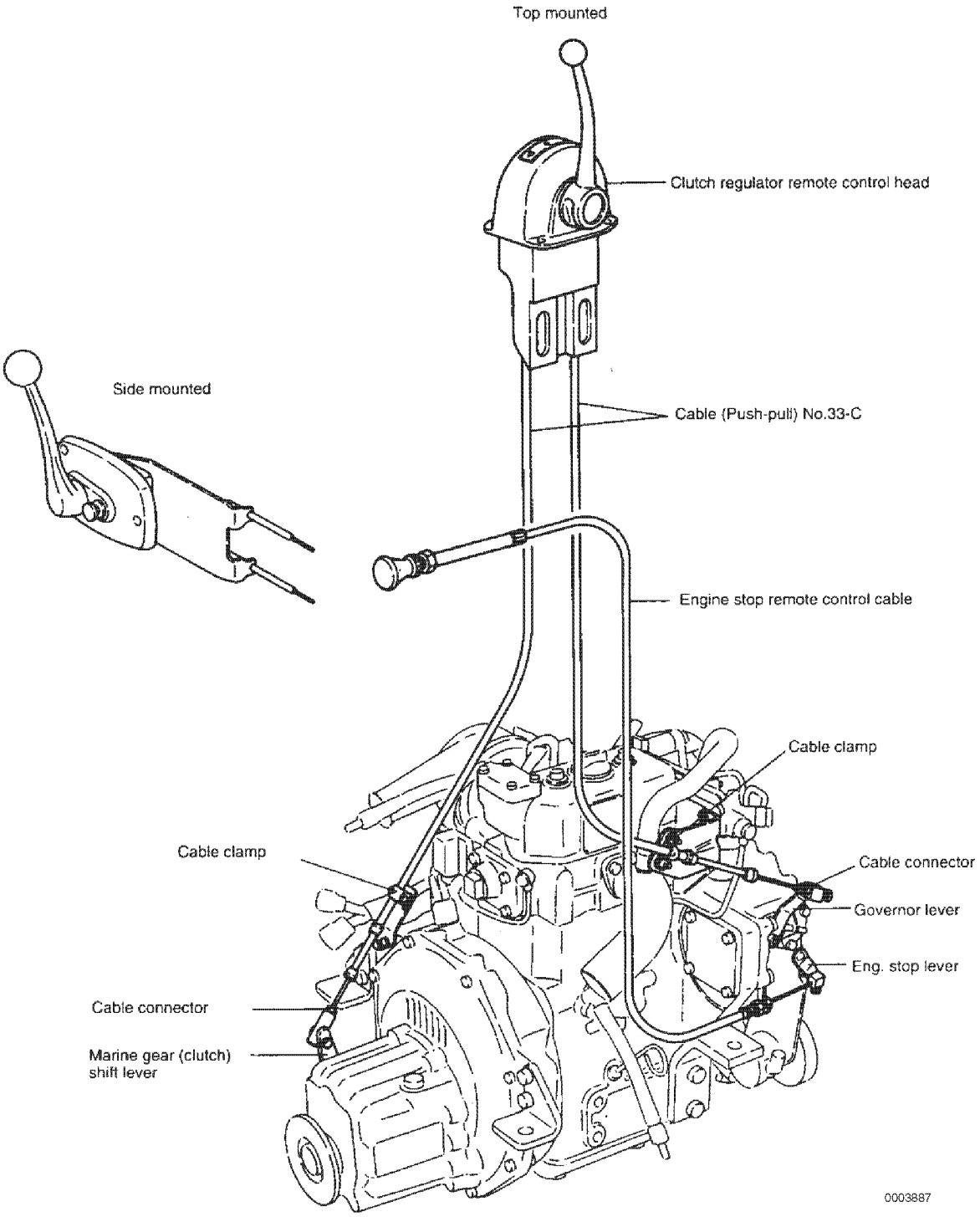


Figure 6-86

Remote Control Head and Cable

Use only super-responsive MORSE control cables. These are designed specifically for use with MORSE control heads.

This engineered system of MORSE cables, control head and engine connection kits ensures dependable and smooth operation with an absolute minimum of backlash.

Remote Control Head

Notes:

- Only use the single lever remote control head for the Yanmar mechanical clutch marine gear.
- The two lever remote control head cannot be used because too large a torque is need to operate the marine gear shift lever at engine high speeds (over 1800 rpm). This exceeds its capacity, and makes the mechanical clutch inoperable.

Refer to the specifications for each engine model to select the appropriate marine gear.

There are two types of remote control head, the top-mounted control and the side-mounted control. Select the type for the installation position.

Top-Mounted Control Type

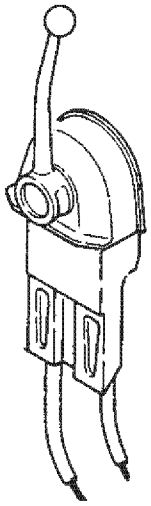


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Figure 6-87

Side-Mounted Control Type

New expanded side-mounted series controls include right and left hand models designed for easier installation and servicing. The side-mounted control can be pre-assembled and installed without removing the side panels.

A pull-out button disengages the clutch for the full throttle range in neutral for safe starting and warm-up.

Controls have FORWARD, NEUTRAL and REVERSE detents and built-in friction to prevent throttle creep.

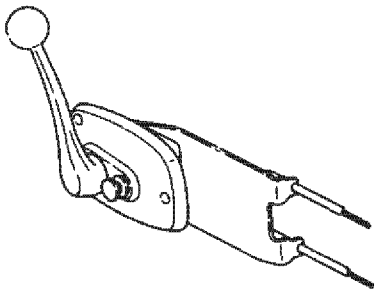

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Figure 6-88

Dual Station Control

The following methods are available for operating an engine from two positions (such as flybridge and cabin).

A: Series Type

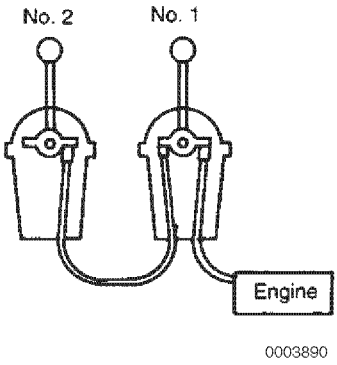


Figure 6-89

The handling force has more resistance because of the use of the relay cable between the No. 1 and No. 2 units. Ensure that the cable stroke at the No. 2 unit has some allowance to compensate for the cable stroke loss caused by the relay to the No. 1 control head.

B: Dual Station Unit Type

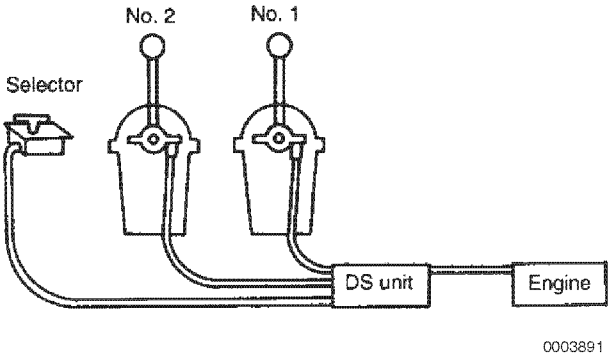
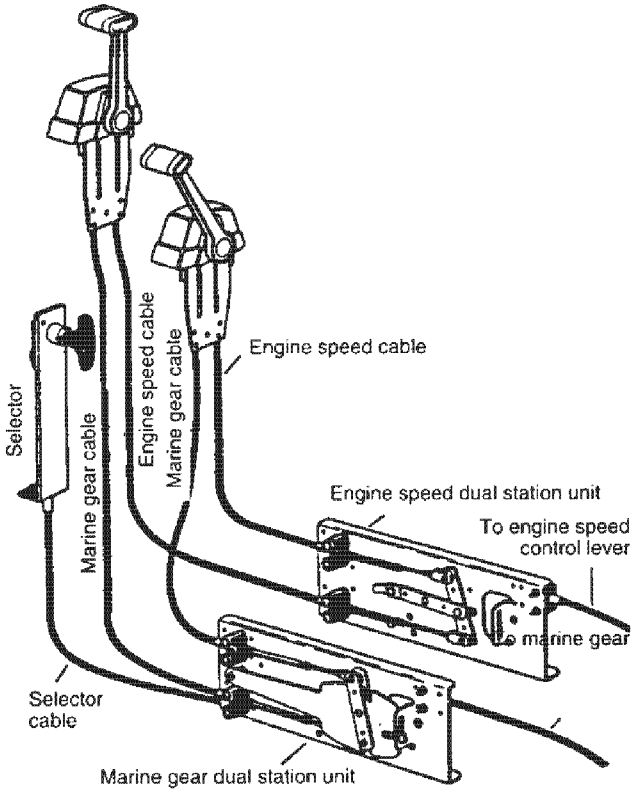


Figure 6-90

Consult the remote control unit maker (MORSE) for the dual station unit.



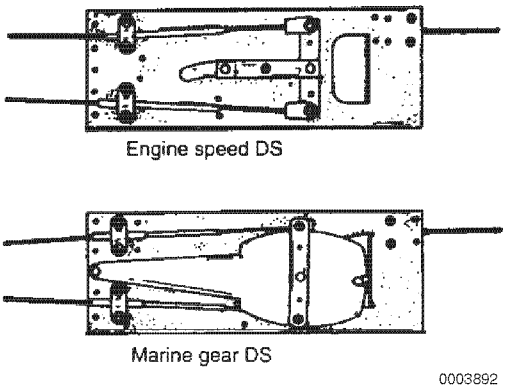


Figure 6-91

C: Hydraulic and Electric Remote Control Unit

The operating force of the control head of the hydraulic / electric remote control device can be smaller than with the mechanical type.

Examples of Electric or Hydraulic Type

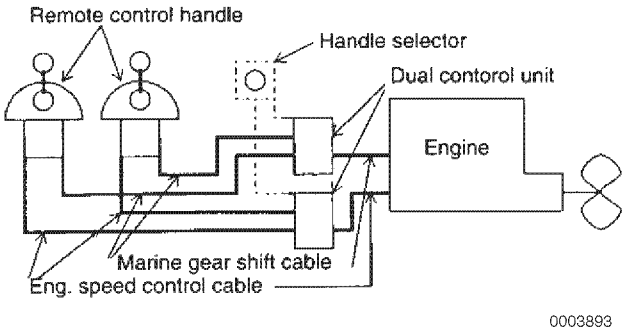


Figure 6-92

These control heads operate the marine gear shift lever or engine throttle lever via the hydraulic cylinder or DC motor by activating the hydraulic valve or sensor unit.

Accordingly, these devices are ideal for 2-station remote control of twin-engine two-shaft propulsion boats or inboard outdrive boats on which shift and throttle lever operation is heavy.

IMPORTANT

When selecting remote control heads:

The unit must have sufficient operating force for the engine throttle and marine gear levers.

The unit must have an adequate operating stroke for the engine throttle and marine gear levers.

Construction of Remote Control System

The remote control permits one-handed control of the engine speed, changes from forward to reverse and stopping.

Fittings that allow for easy connections to the remote control cables with the governor lever and marine gear are provided with the remote control set.

The use of MORSE remote control cables, clamps and a remote control head are also provided for. The engine stopping device is electric and will be explained in the section on *Engine Stop Solenoid*.

Remote Control Device Components

	Description	Type	Yanmar Part Number
Remote Control Head	MORSE, MT3 top mount	MT3	D24070-86310
	MORSE, MV side mount	MV	D28170-86300
Remote Control Cable	MORSE, 33C x 4m	RC4	D24070-86500
	MORSE, 33C x 7m	RC7	D29470-86500
Engine Stop Cable (Manual engine stop)	YANMAR Made, 3m	SC1	D28170-67500
	YANMAR Made, 4m	SC2	D29470-67500
	YANMAR Made, 7m	SC3	D29470-67510

MT3-Type

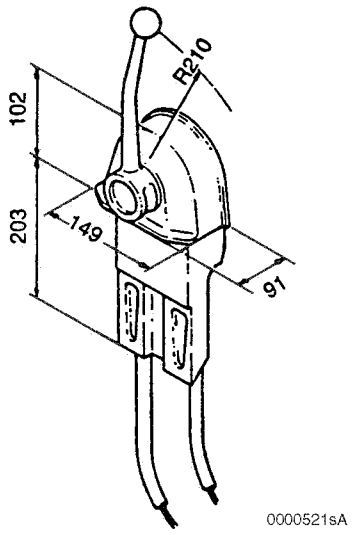


Figure 6-93

MV-Type

Newly expanded MV-series controls **(Figure 6-94)** include right- and left-hand models designed for easier installation and servicing. The MV control can be pre-assembled and installed without removing the side panels.

A pull-out button disengages the clutch for the full throttle range in neutral for safe starting and warm-up.

MV controls have forward, neutral and reverse detents and built-in friction to prevent throttle creep.

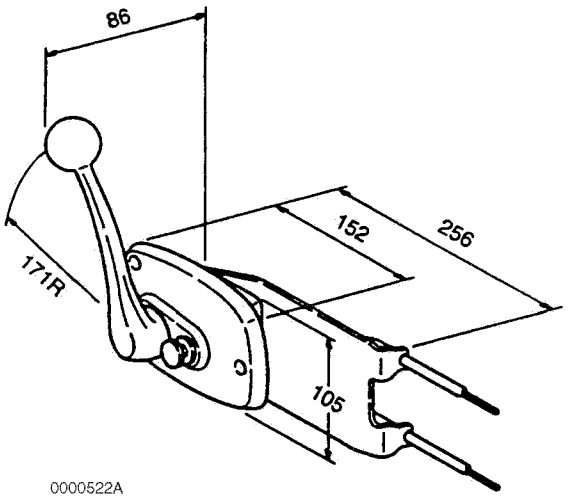


Figure 6-94

Remote Control Cable

MORSE-type 33-C push-pull control cables.

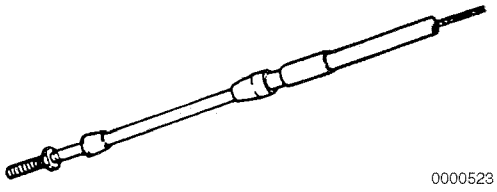


Figure 6-95

Use only Super-Responsive MORSE Control Cables. These are designed specifically for use with MORSE control heads. This engineered system of MORSE cables, control head and engine connection kits ensures dependable, smooth operation with an absolute minimum of backlash. The thread size on the cable ends is 10-32, UNF-2A. Travel is up to 76.2 mm (2.99 in.).

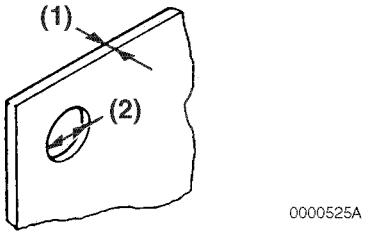
Engine Stop Cable

The stop lever of the fuel injection pump is connected to the solenoid with a connecting rod. The device is operated by the stop switch on the instrument panel.

1 – Yanmar-made ø1.5 mm

Figure 6-96

Installation of Engine Stop Knob

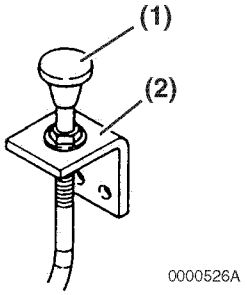


1 – 3 - 5 mm
2 – ø11.5 - 12 mm hole

Figure 6-97

The engine stop knob is common to both stop remote control and decompression remote control.

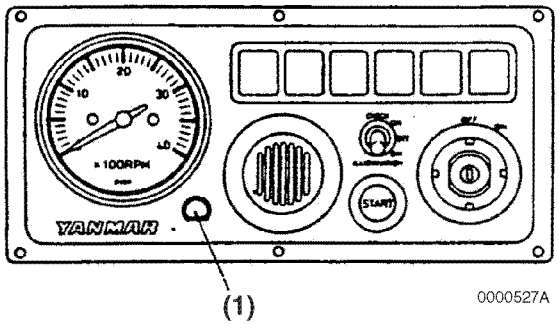
Firmly install the knob with a bracket in a suitable place that is convenient for operation.



1 – Knob **2 – Bracket**

Figure 6-98

When using the B, B2 and New B-type instrument panel, install the knob at the knob hole provided in the panel.



1 – Knob Installation Hole

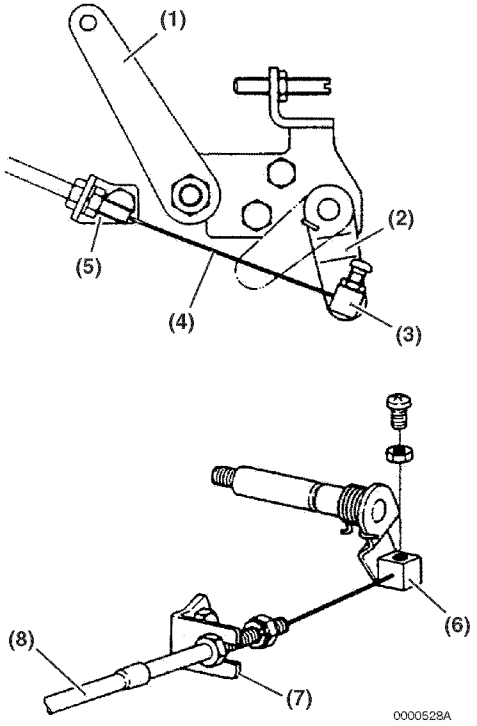
Figure 6-99

The knob installation hole is not completely stamped out. Remove the knockout to install the engine stop knob.

Wiring of Engine Side

Connect the engine stop control cable as shown. **(Figure 6-100)** After installation, ensure that the cable moves freely throughout its full range.

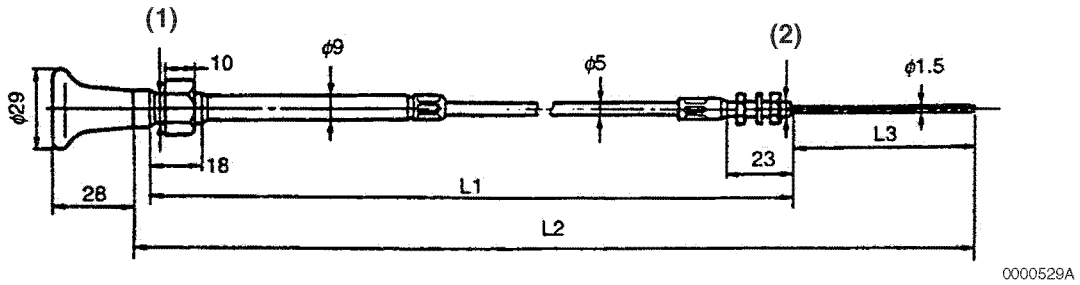
The metal connector fitting has a hole diameter of 2.5 mm (0.1 in.) to accommodate the cable. A cable of 1.5 - 2.5 mm (0.06 - 0.1 in.) diameter can be used in the connector.



1 – Governor Lever
2 – Engine Stop Lever
3 – Cable Connector
4 – Remote Control Cable
5 – Bracket
6 – Cable Connector
7 – Bracket
8 – Remote Control Cable

Figure 6-100

Dimensions of Engine Stop Cable (Yanmar-Made)



1 – M11 x P1.25 (thread diameter) **2 – M6 x P1.0 (thread diameter)**

Figure 6-101

Type	Part Name	L1	L2	L3	Yanmar Part Number
SC1	Engine stop cable 3 m	3000 mm	3140 mm	134 mm	D28170-67500
SC2	Engine stop cable 4 m	3854 mm	4000 mm	140 mm	D29470-67500
SC3	Engine stop cable 7 m		7000 mm		D29470-67510

Cable Clamp

Yanmar cable clamps **(Figure 6-102)** are standard parts. They are fitted to the brackets on the engine and marine gear.

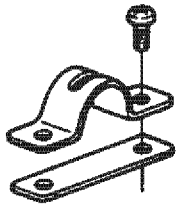


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Figure 6-102

Cable Connector

Yanmar cable connectors are standard parts. They are fitted to the marine gear shift lever and engine speed governor (throttle) lever.

Engine Speed Lever Installation

The metal connector, which joins with the damping spring, is at the tip of the governor (throttle) lever. Screw the cable into the fitting.

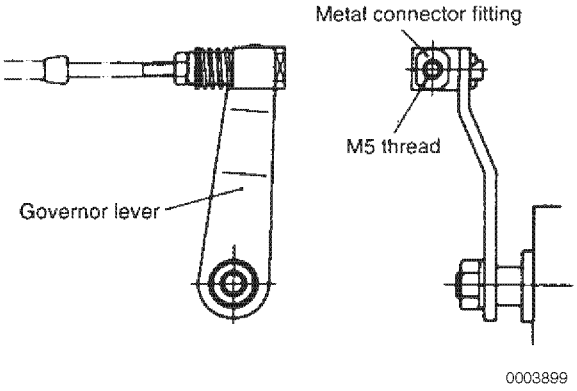

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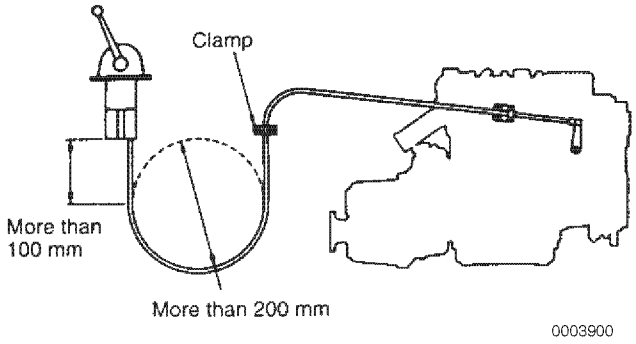
Figure 6-103

Control Cable Installation

1. The minimum radius of cable bending should be 200 mm (7.87 in.).
2. The outer cable should be bent, if required, at a point more than 100 mm (3.94 in.) from the outer cable clamp in order to protect the clamp from strain **(Figure 6-104)**.



0003900

Figure 6-104

3. The exposed portion of the inner cable should be coated with a water-resistant grease for rust prevention and smooth movement of the cable **(Figure 6-105)**.

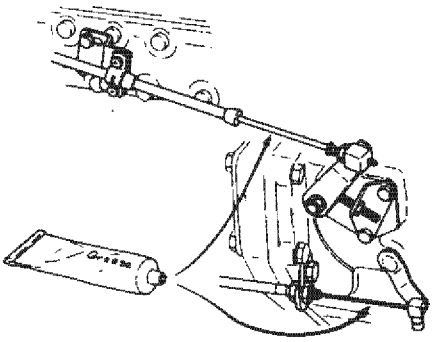


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Figure 6-105

4. The cable should be routed so that it does not come into contact with the heated area of the engine, sharp edges or moving parts.
5. Do not clamp wire harnesses or other electrical wires to the cable **(Figure 6-106)**.

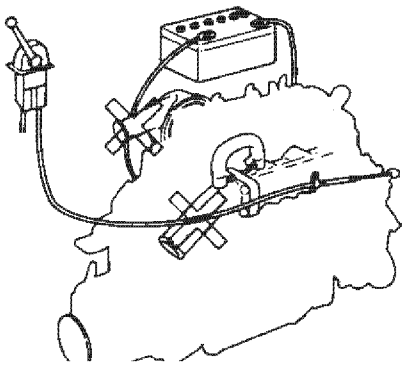


Figure 6-106

NEUTRAL SAFETY SWITCH

To prevent the engine from starting when the shift lever is in FORWARD or REVERSE, a neutral safety switch is installed.

The neutral safety switch prevents the starting motor from running except when the shift lever is in NEUTRAL, the engine will not start when the shift lever is in FORWARD or REVERSE.

The neutral safety switch can be installed to either the remote control handle or to the marine gear.

Note: Installation of this device on pleasure boats is required by law in some countries including Japan.

Neutral Safety Switch Wiring Example

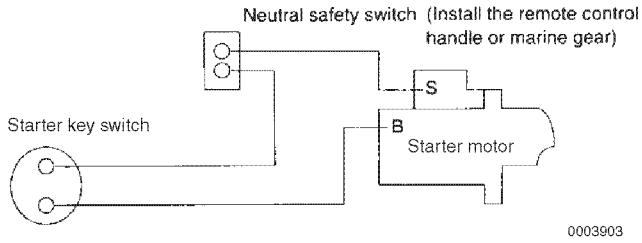


Figure 6-107

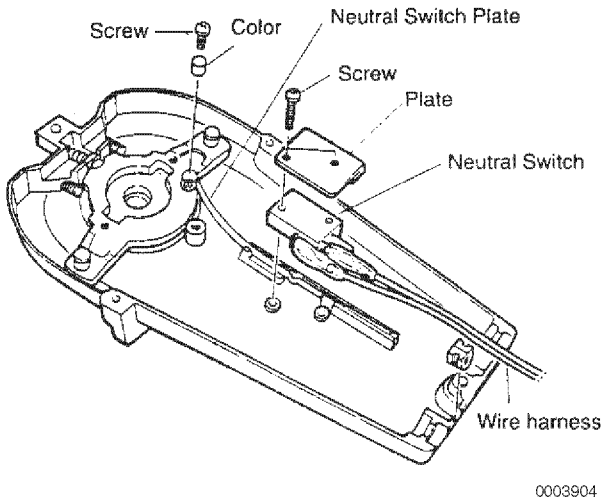
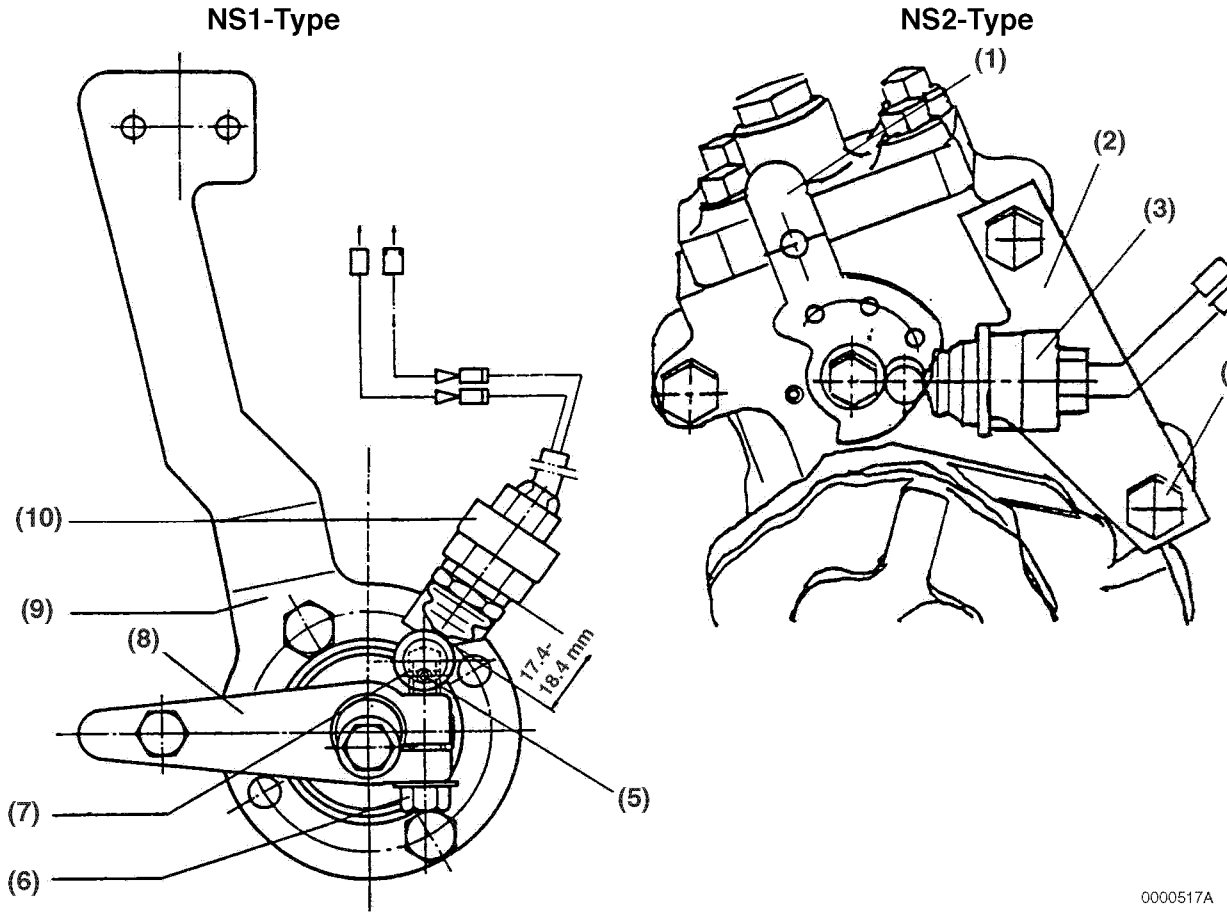


Figure 6-108

Type	Yanmar Part Number
NS1	D77074-06020
NS2	D19573-77110

Remote Control Head with Neutral Safety Switch



1 – Shift Lever
2 – Switch Bracket
3 – Neutral Safety Switch
4 – Bolt, M10 x 85
5 – Clamp Bolt, M4 x 8
6 – Bolt, M8 x 30
7 – Activator of Safety Switch
8 – Shift Lever
9 – Cable Bracket
10 – Safety Switch Rated Capacity: DC12V 30A

Figure 6-109

ELECTRONICALLY-CONTROLLED ENGINES

Electronically-controlled engine installation requires special considerations that are not generally encountered in mechanically controlled installations. While electronically-controlled engines have added features like data logging, and precision timing algorithms, they are susceptible to electrical noise caused by voltage variations, inadequate shielding or poor grounding practices.

Battery Requirements

Electronically-controlled engines are equipped with sensitive circuitry that requires a constant, well-regulated voltage supply. Batteries must be properly sized to accommodate the engine electrons and auxiliary electrical equipment onboard.

Battery Connection Designs

Battery post connections must be solid bolt-type with tight contact. Loose or undersized connections could introduce excessive electrical resistance, causing unacceptable voltage drop.

Grounding Requirements

Electronically-controlled engines usually have traditional or two-pole starter wiring systems. In either case, grounding must be in one central location. Multiple grounding points can produce ground loops. These ground loops can cause electrical noise problems that interfere with normal electronics operation.

FUEL SYSTEM

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- **Diesel fuel is flammable and explosive under certain conditions.**
- **Only fill the fuel tank with diesel fuel. Filling the fuel tank with gasoline may result in a fire and will damage the engine.**
- **NEVER refuel with the engine running.**
- **Wipe up all spills immediately.**
- **Keep sparks, open flames or any other form of ignition (match, cigarette, static electric source) well away when refueling.**
- **NEVER overfill the fuel tank.**
- **Fill the fuel tank. Store any containers containing fuel in a well-ventilated area, away from any combustibles or sources of ignition.**
- **Failure to comply will result in death or serious injury.**

0000005en

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- Place an approved container under the air bleed port when you prime the fuel system. Never use a shop rag to catch the fuel. Wipe up any spills immediately. ALWAYS close the air bleed port after you complete priming the system.
- Wear eye protection. The fuel system is under pressure and fuel could spray out when you open the air bleed port.
- If the unit has an electric fuel pump, turn the key switch to the ON position for 10 to 15 seconds, or until the fuel coming out of the air bleed port is free of bubbles, to allow the electric fuel pump to prime the system.
- If the unit has a mechanical fuel pump, operate the fuel priming pump several times until the fuel coming out of the air bleed port is free of bubbles.
- Failure to comply will result in death or serious injury.

0000006en

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- When you remove any fuel system component to perform maintenance (such as changing the fuel filter) place an approved container under the opening to catch the fuel.
- NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.
- Wipe up any spills immediately.
- Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.
- Failure to comply will result in death or serious injury.

0000009en

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- NEVER use diesel fuel as a cleaning agent.
- Failure to comply will result in death or serious injury.

0000012en

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- **Diesel fuel is flammable and explosive under certain conditions.**
- **Be sure to place the diesel fuel container on the ground when transferring the diesel fuel from the pump to the container. Hold the hose nozzle firmly against the side of the container while filling it. This prevents static electricity buildup which could cause sparks and ignite fuel vapors.**
- **NEVER place diesel fuel or other flammable material such as oil, hay or dried grass close to the engine during engine operation or shortly after shutdown.**
- **Failure to comply will result in death or serious injury.**

0000014en

CAUTION

- **Only use diesel fuels recommended by Yanmar for the best engine performance, to prevent engine damage and to comply with EPA warranty requirements.**
- **Only use clean diesel fuel.**

0000004enMarine

The fuel system includes the fuel tank, fuel piping from the fuel tank to the fuel feed pump, and fuel return piping from the fuel injection pump to the fuel tank.

An extra fuel feed pump may be attached when the installation position of the fuel tank is low. Also, an extra fuel filter with a fuel / water separator may be installed to remove water and sediment from the fuel.

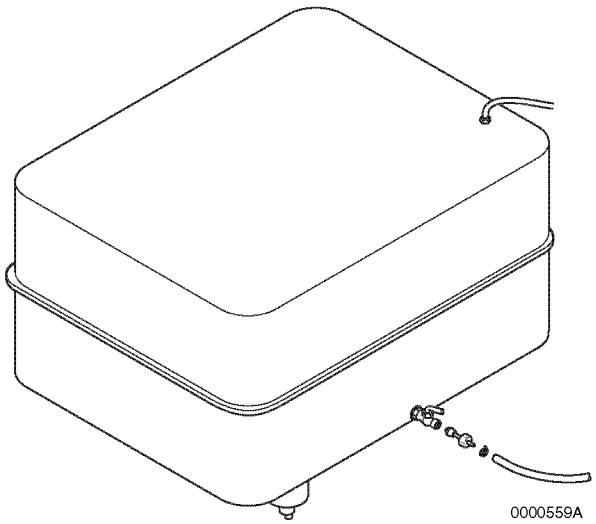
Both the fuel feed pump inlet and fuel injection nozzle fuel return outlet on the engine side are provided with rubber hose joint, to which a rubber hose can be connected.

Note: Be sure that the fuel tank specifications and fuel line piping comply with local safety regulations where applicable.

Fuel Tank

Capacity of Fuel Tank

The capacity of the fuel tank is determined during the design stage of the boat with consideration to the cruising range, inboard space, fuel consumption of the engine to be installed, etc.



0000559A

Figure 6-110

To find the fuel consumption of the engine, use the specific fuel consumption curve (g/hp-hr or g/kW-hr).

The calculation is as follows:

$$\text{Fuel consumption: } F = \frac{f \times hp(\text{or } kW)}{S \times 1000} \text{ L/hr}$$

S = Specific gravity of diesel fuel (diesel fuel: 0.83)
f = Specific fuel consumption: g/hp-hr or g/kW-hr
Refer to the performance curve for the engine data of each engine.

Example:

What is the fuel consumption of the 6LY-UTE (315 hp / 3300 rpm) when used for 2 hours at continuous rating (assume the specific fuel consumption to be 165 g/hp-hr.)?

$$F = \frac{165 \times 315}{0.83 \times 1000} = 62.62 \text{ L/hr} \times 2 \text{ hrs} = 125.24 \text{ L}$$

Note: For power boat applications, it is recommended to allow some reserve in the capacity of the fuel tank and to install the tank on the hull bottom or close to hull side where indirect cooling is expected. Surplus fuel returning from the engine to the fuel tank is heated to a high temperature. This raises the overall temperature of the fuel in the tank when the tank's capacity is small. The output of diesel engines tends to drop when fuel of over 40°C is supplied.

Fuel Tank Installation

The fuel tank must be installed within the distance of the suction capacity of the engine's fuel feed pump. Install the fuel tank as follows:

1. Install the fuel tank within the head of the fuel feed pump of the engine.
2. When installing the fuel tank lower than the engine's fuel feed pump, install the fuel tank within the suction head capacity of fuel feed pump.
3. It is not necessary to consider the suction head of the fuel feed pump when the fuel tank is installed higher than the engine's fuel feed pump (fuel at a higher level flows smoothly under gravity to the lower fuel feed pump).
4. Refer to the engine data for each engine model for the suction capacity of the fuel feed pump.

Notes:

Except for the higher installation position above, when installing the fuel tank beyond the suction capacity of the fuel feed pump, you must also install an auxiliary fuel feed pump and a fuel service tank. The fuel piping layout is as follows:

Main fuel tank → auxiliary fuel feed pump → fuel service tank → water trap → fuel filter → fuel feed pump.

The auxiliary fuel feed pump supplies fuel to the fuel service tank from the main fuel tank. The engine's fuel feed pump supplies fuel from the main fuel tank.

Select a service tank that can hold sufficient fuel for engine operation. The auxiliary feed pump is activated by a sensor installed in the service tank when a given amount of fuel is consumed. It replenishes the service tank with the same amount of fuel from the main tank.

Fuel Tank Height

The fuel tank should be installed at the highest possible point as close to the engine as possible. For the suction head, refer to the fuel feed pump capacity information in the engine data for each engine.

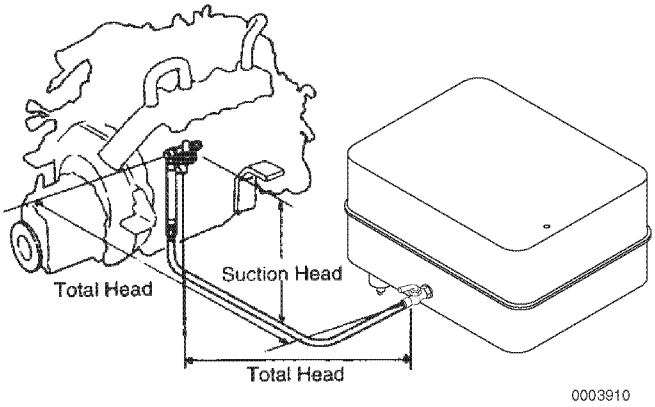


Figure 6-111

Piping

1. The hose must be as straight as possible. Minimum bend radius: 50.0 mm (2.0 in.) or more.
2. Be careful that the fuel piping does not touch the engine exhaust manifold or other hot parts.
3. Make sure that there are no leaks.
4. When using separately purchased copper or steel tube for the fuel piping, secure the pipe with clamps **(Figure 6-112)** approximately every 150 - 200 mm (5.0 - 8.0 in.) on the bulkhead or hull to prevent the pipe from breaking due to vibrations.

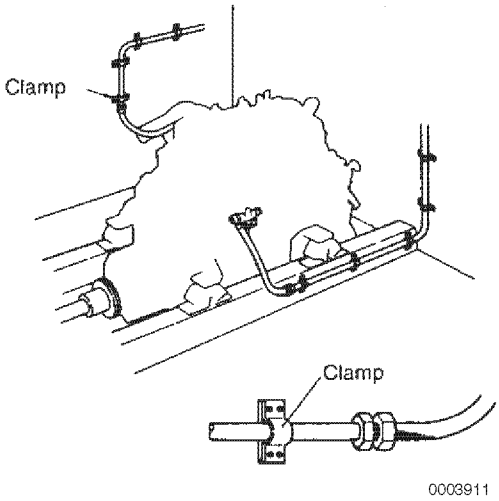


Figure 6-112

Auxiliary Fuel Feed Pump

When the installation position of the fuel tank is considerably lower than the engine or the piping is long, calculate the suction head of the fuel feed pump and install an auxiliary fuel feed pump. When using an electric fuel feed pump, wire it so the pump operates only during engine operation.

Additional Fuel Filter with Water Trap

The engine is provided with an element-type fuel filter, but in order to eliminate water and dirt completely, it is recommended to install an extra fuel filter with a water trap. Select a suitable position in the piping between the fuel feed pump and the fuel tank. The location must be free from vibrations and be accessible for filter inspection and replacement.

Note: Do not install the extra fuel filter onto the engine.

1. Extra fuel filter capacity: The extra fuel filter with water trap should have a current velocity performance of more than 1.5 times the delivery volume of the fuel feed pump.
2. Direct injection engine: Always use an extra fuel filter and water trap for direct injection engines.

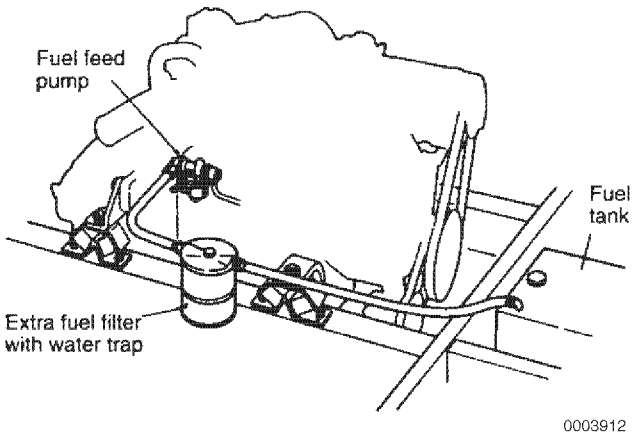


Figure 6-113

Fuel Service Tank

A fuel service tank is available as an option for all engine models. The capacity is 30 L (8 gal) and is triangular in shape **(Figure 6-114)**. A rubber hose 2 m (79 in.) in length is attached to feed fuel from the fuel tank to the fuel pump. A connection to return fuel is provided at the top of the fuel tank. The overflow fuel can be returned to the tank by connecting a rubber hose from the fuel valve.

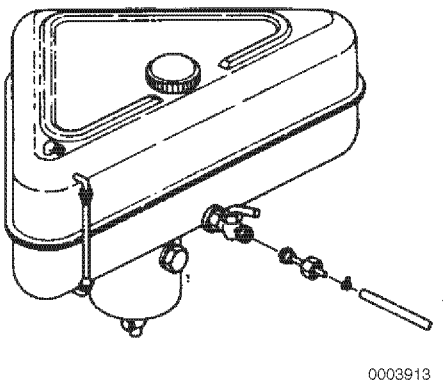


Figure 6-114

Specifications

Type:	FT1
Yanmar Part Number	D28170-55500
Material	Steel Plate
Capacity	30 L (8 gal)
Thread of Outlet Cock	PF 1/2
Size of Rubber Hose	ϕ7/ϕ13 x 2000 mm

Dimensions

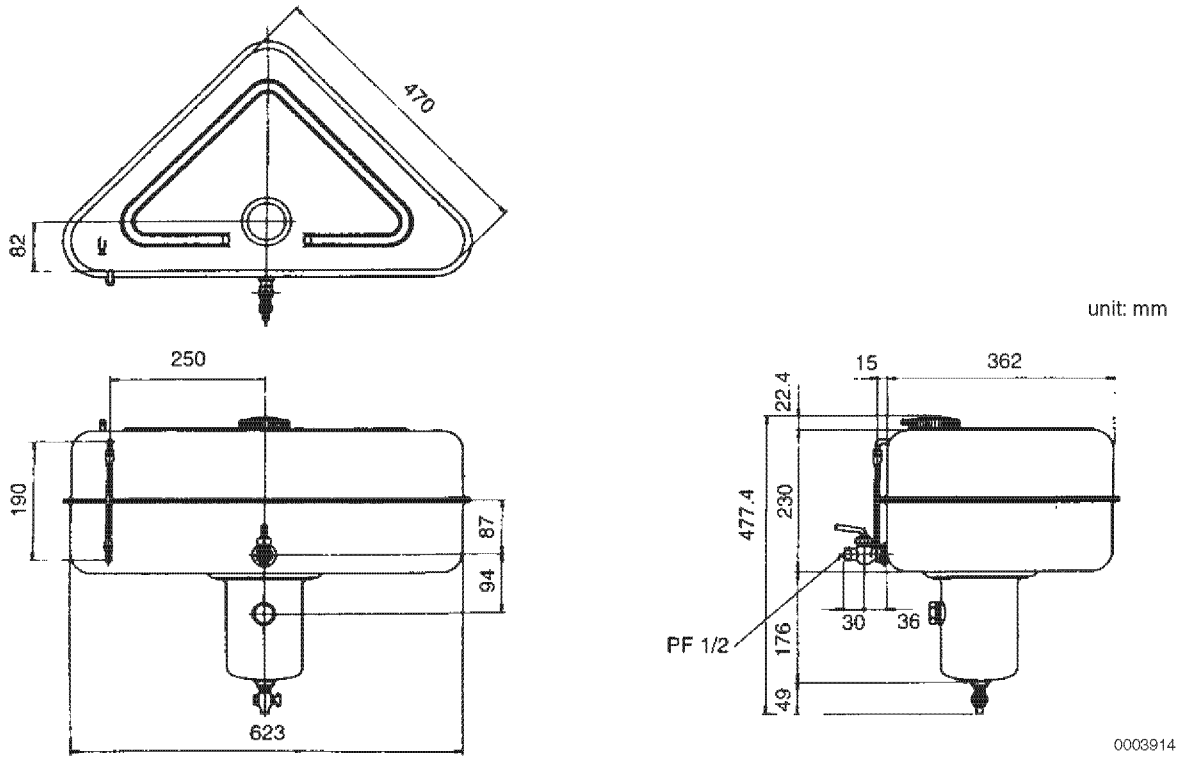
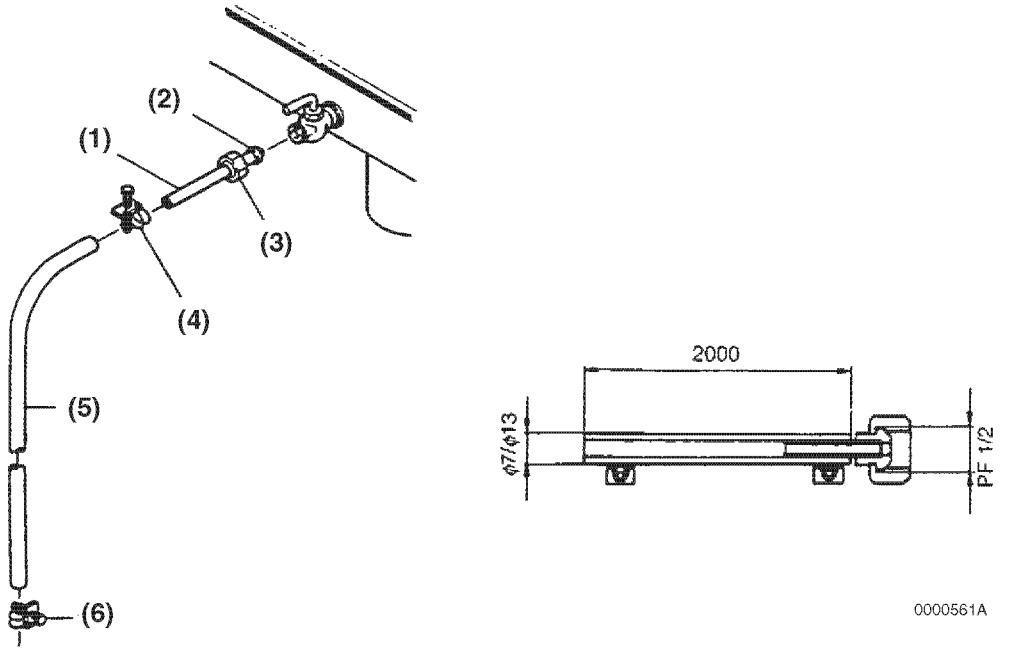


Figure 6-115

The fuel tank is manufactured of pressed steel plate and a baffle plate is provided inside to prevent fuel splashing in the tank and to counter the rolling and pitching of the boat. To drain water and dirt from the tank, a drain pan and plug are provided at the tank bottom. The fuel feed port is on the front of the cover, and a level gauge is on the front side.

Rubber Hose



1 – Copper Pipe φ6 mm / φ8 mm x 45 mm
2 – Fitting
3 – Cap Nut
4 – Clamp φ14 mm
5 – Rubber Hose φ7 mm / φ13 mm x 2000 mm
6 – Clamp φ14 mm

Figure 6-116

The fuel return pipe is not available from Yanmar. Use an oil-proof rubber hose with a 13 mm inner diameter. Connect return pipe to the fittings to the fuel tank and the fuel injection valve sides. Secure the hose with clamps.

Fuel / Water Separator

Specifications

Type		FWS 1	FWS 2
Yanmar Part Number		D19187-55200 D27692-55200	D27610-55150
Filter Material		Glass Wool	←
Pore Size	μm	150	←
Flow Resistance	mmHg / L/min.	30 / 3	12 / 2
Filtration Volume	cm^3	100	42.6
Dimensions			
A	mm	216	163
B	ϕmm	102.8	85
C	mm	40	←
D	ϕmm	116	99
E	mm	2 x ϕ10.5	2 x ϕ11
F (Thread Hole)	mm	M14 x 1.5	←
G (Thread Hole)	mm	M14 x 1.5	←
H (Thread Hole)	mm	M14 x 1.5	M8 x 1.25

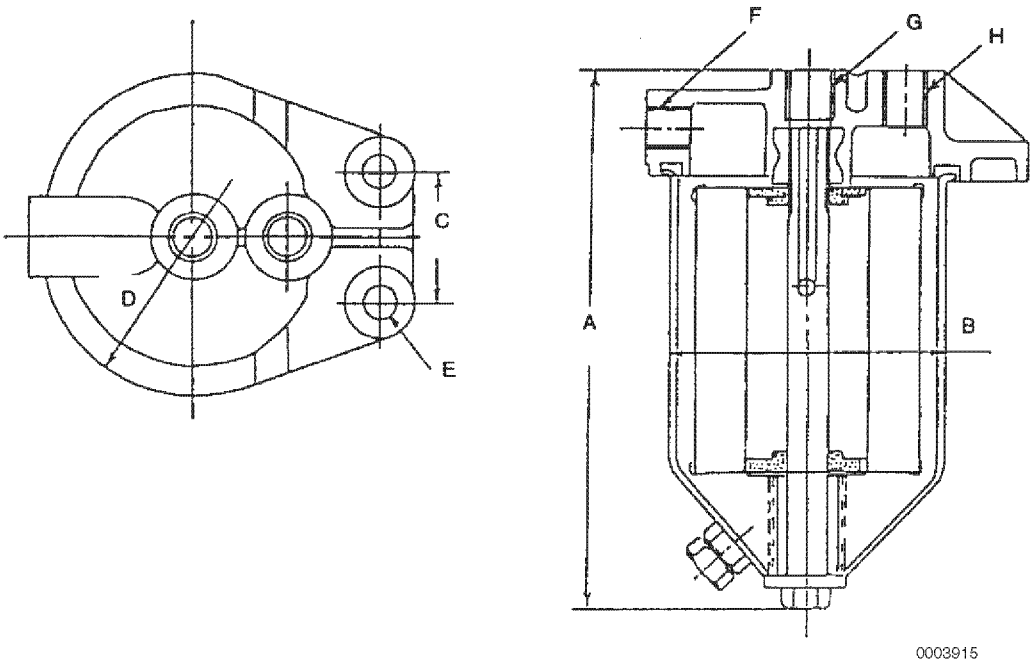


Figure 6-117

COOLING SYSTEMS

Seawater Cooling

The seawater is drawn up by the seawater pump through a seacock installed on the hull. The water from the seawater pump branches out in two directions: one branch enters the cylinder jacket and the other bypasses the cylinder jacket and enters the exhaust manifold.

The water that enters the cylinder jacket cools the cylinders and then goes up to the cylinder head to cool the cylinder head.

The thermostat installed between the cylinder head and exhaust manifold controls the cooling water circuit by monitoring the water temperature.

The thermostat opens gradually as the water temperature rises. This diverts cooling water from the bypass circuit to the cylinder jacket and cylinder head.

As the water temperature falls, the thermostat closes gradually, more water flows into the bypass circuit, and less to the cylinder jacket or cylinder head. For the detailed cooling circuit, refer to the piping diagrams in the Engine Data for each engine.

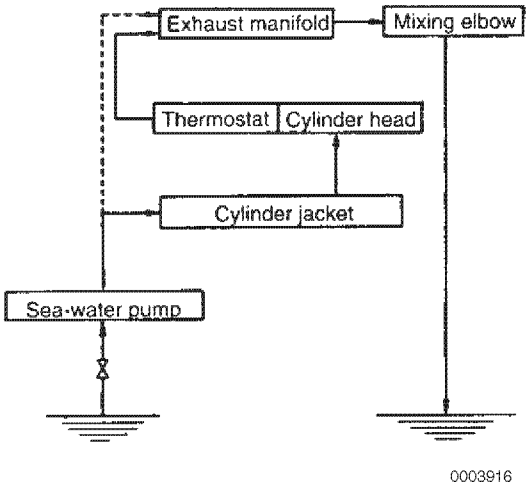


Figure 6-118

Closed Cooling System

Engine coolant from the heat exchanger is circulated around the cylinder block and cylinder head by the engine coolant pump. The pump forces the coolant through the cylinder block and cylinder head cooling passages and back to the heat exchanger, where seawater carries away the heat. The coolant circulation is controlled by the thermostat.

The thermostat is closed while the coolant temperature is low. Engine coolant flows through the bypass passage to the suction side of the engine coolant pump and circulates inside the engine bypassing the heat exchanger.

Some engine models equipped with a closed cooling system have a water-cooled turbocharger, intake air cooler, and engine oil cooler. For details of the cooling circuit, refer to the piping diagrams in the Engine Data for each engine.

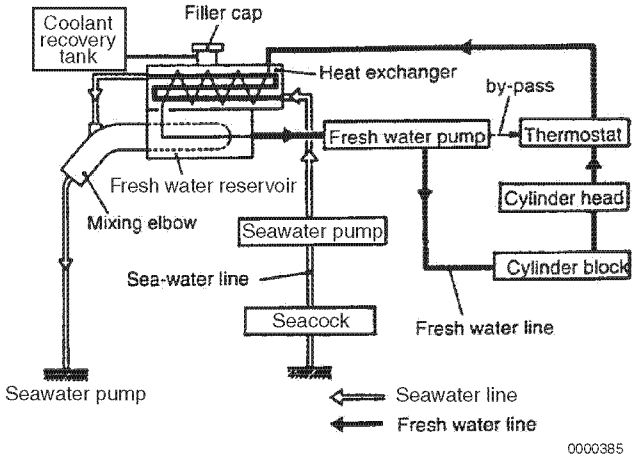
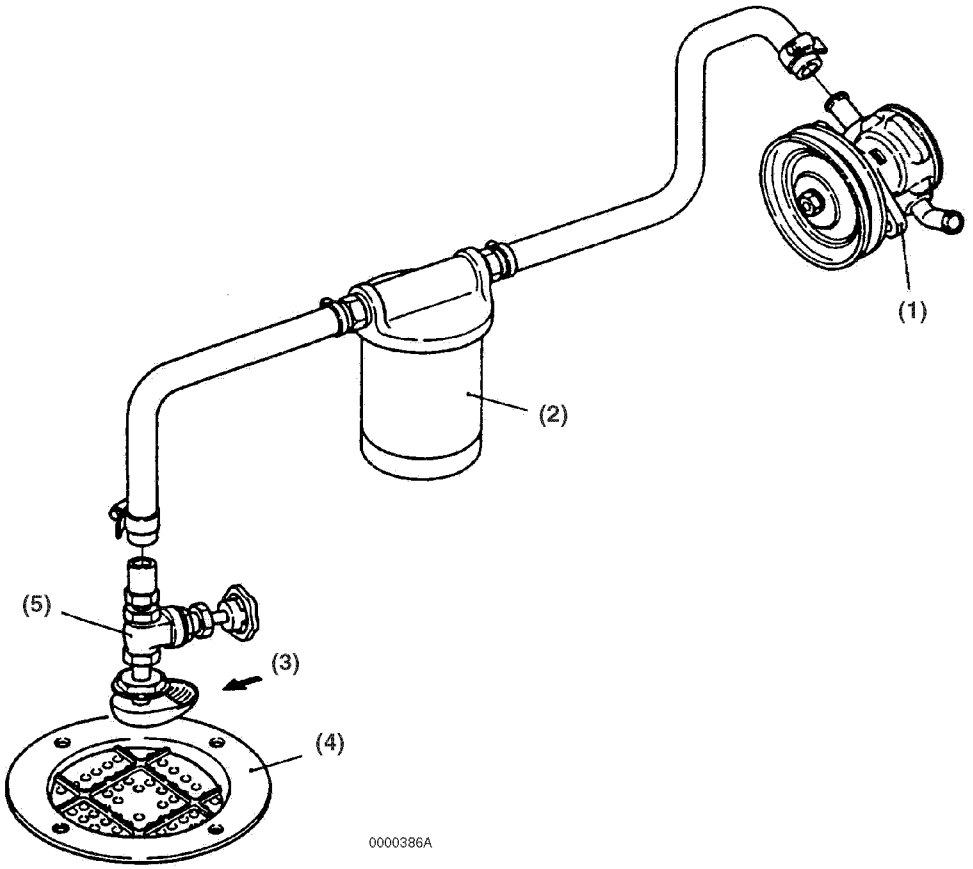


Figure 6-119

Seawater Cooling System



1 – Seawater Pump
2 – Seawater Strainer
3 – Cooling Water
4 – Seacock Cover
5 – Seacock

Figure 6-120

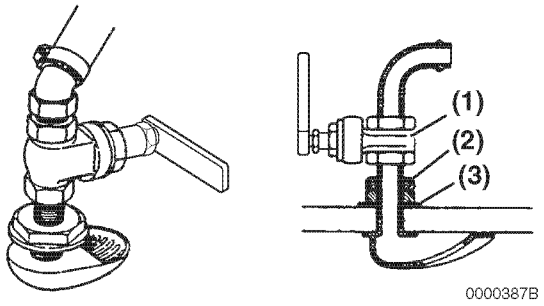
Seawater is drawn from the seawater inlet by the seawater pump and flows through the cooling system or heat exchanger to cool the engine.

After cooling the engine components, the seawater then passes through the exhaust / water mixing elbow and is discharged together with the exhaust.

The seawater inlet consists of the seacock and the water hose which connects to the cock to the seawater pump. When the boat is operated in dirty water, provide a seawater strainer between the seacock and the cooling water pump.

Note: Install the seawater pump at an appropriate distance from the seacock, considering the seawater pump capacity and the total head and suction head. If the pump is installed in an inappropriate location, the resulting insufficient cooling water causes engine overheating.

Seacock



1 – Seacock
2 – Double Nut
3 – Washer

Figure 6-121

Dimensions

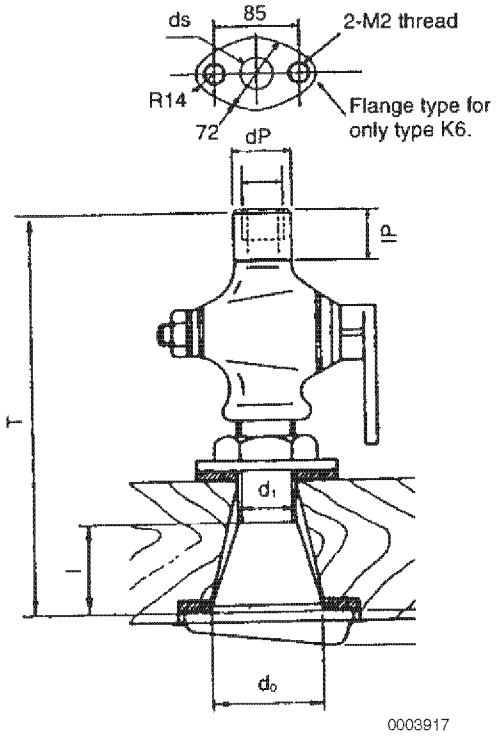


Figure 6-122

Type	Yanmar Part Number	dp (mm)	ds (mm)	IP (mm)	d_1 (mm)	d_0 (mm)	l (mm)	T (mm)
K1	D04214-48501	ϕ14	-	13	M16	ϕ31	34	103
K2	D24770-48101	ϕ18	-	13	M22	ϕ50	42	120
K3	D29795-48100	ϕ26	-	28	M32	ϕ79	33	190
K4	D24411-48100	ϕ32	-	35	M32	ϕ79	33	195
K5	D27610-48201	-	PT1-1/4	-	M39	ϕ86	-	179
K6	D28610-48100	-	ϕ40	-	M50	ϕ112	-	204

Positioning the Seacock

Locate the seawater inlet well under the waterline. When the hull rolls, the inlet must remain submerged beneath the waterline.

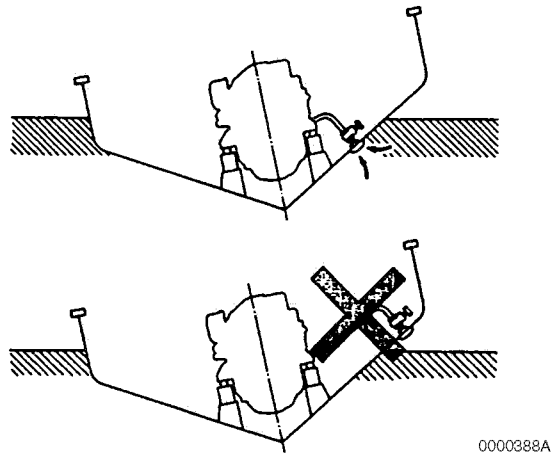


Figure 6-123

Determining the Direction of the Seacock

In power boat applications, the inlet of the seacock and the kingston cover must be fixed in the cruising direction. In the sailboats applications, the direction must be reversed.

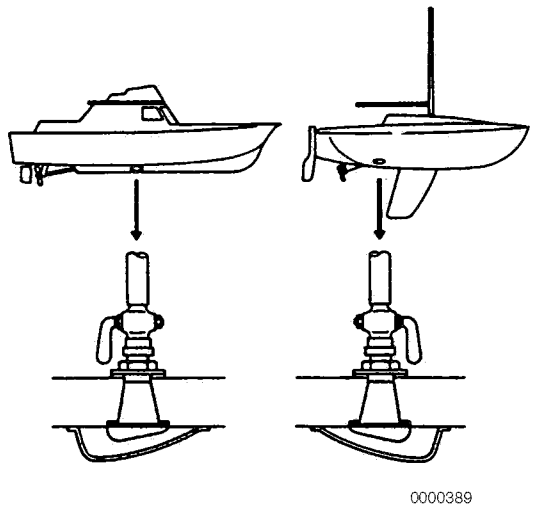


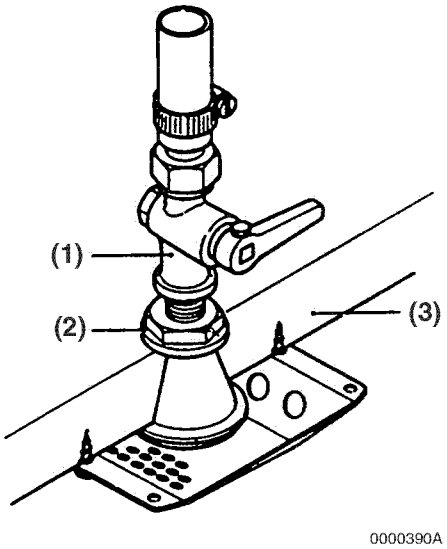
Figure 6-124

Seacock Installation

1. Determine the position of the cooling water pipe and the direction of the cooling water pump inlet joint.
2. Grind the contact face of the seacock hole drilled in the hull bottom.
3. Install the cock using canvas on the outside of the hull and canvas or rubber packing on the inside.
4. After tightening the nuts of the seacock, coat the attachment at both the inside and outside hull surfaces with a sealing agent (silicone rubber, etc.).
5. After installing the seacock, ensure that the cock operates properly. If necessary, change the intake direction of the cock and coat the threaded parts with sealing agent.

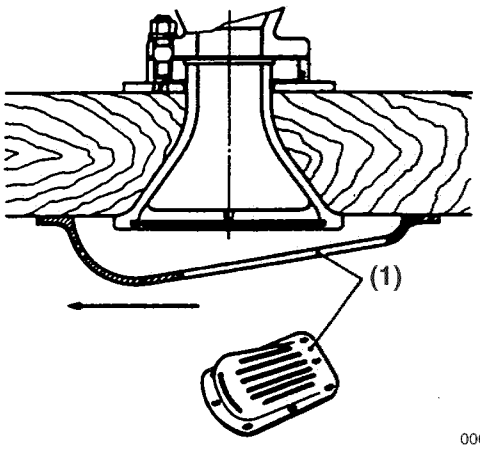
Scoop Strainer

The inlet section must have a double bottom to prevent obstructions and engine overheating. This can arise when foreign matter is sucked in at the seacock inlet port.



1 – Seacock
2 – Packing
3 – Hull

Figure 6-125



1 – Scoop Strainer

Figure 6-126

Attach the scoop strainer firmly to the hull with screws.

Piping

Install a seawater-resistant, oil-proof rubber hose between the seacock and the seawater pump.

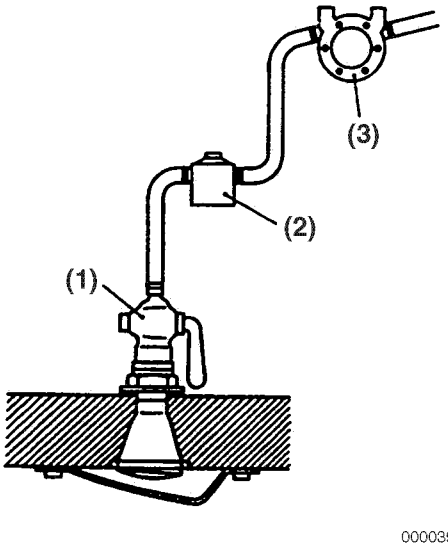
Use a length of hose that is as short as possible and with as few bends as possible. A long, sharply bent hose may not draw water efficiently.

Do not apply tensile stress between the seacock and the seawater pump. Allow enough length in the hose to allow for engine vibration and movement.

When the hose passes through the bulkhead, protect it from damage caused by rubbing. Connect the rubber hoses to the seacock and seawater pump inlet. Secure with hose clamps. Seal with a non-hardening compound.

Seawater Strainer

Seawater damage results from foreign matter entering the cooling system with seawater. The seawater strainer must be attached between the seacock and the seawater inlet.



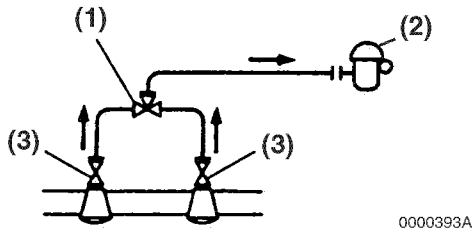
1 – Seacock
2 – Seawater Strainer
3 – Seawater Pump

Figure 6-127

Attach the seawater strainer at a suitable height above the load waterline to the bulkhead, etc.

Using Two Seacocks

When one of the seacocks becomes clogged, operation can be switched to the other while the clogged seacock is being cleaned. If a three-way cock is installed, this operation can be performed while underway.



1 – Three-Way Cock
2 – Cooling Water Pump
3 – Seacock

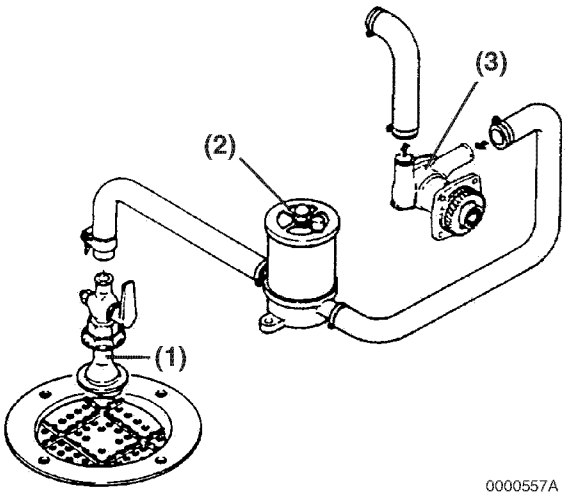
Figure 6-128

Seawater Strainer

When operating the engine in areas where the seawater contains a large amount of mud, sand or other foreign matter, a seawater filter must be installed between the seacock and the seawater pump.

Inspect the seawater filter periodically and clean as needed. Remove the dirt and sand from the bottom of the filter.

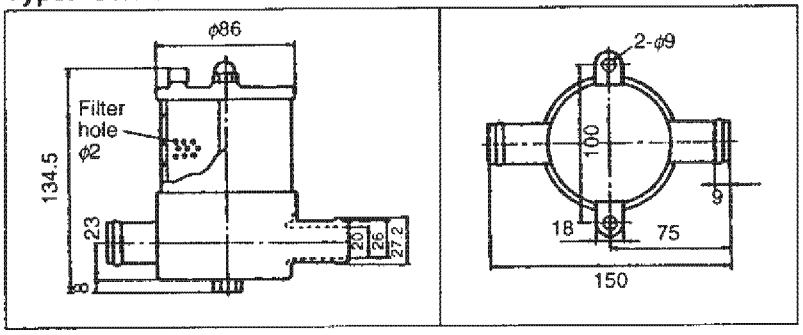
Note: The rubber hose attached to the seawater filter is approximately 1.0 m (39 in.) long.



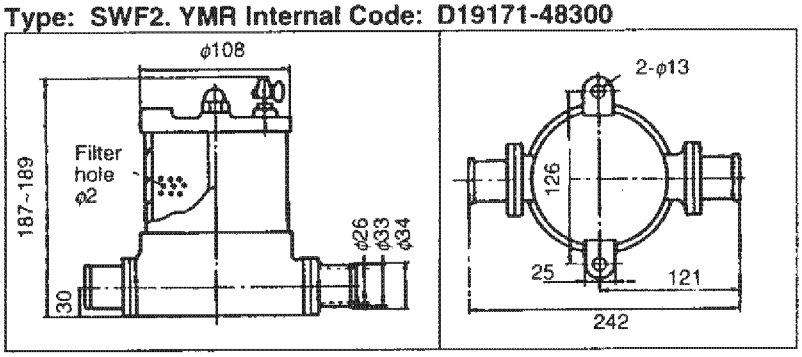
1 – Seacock
2 – Seawater Strainer
3 – Seawater Pump

Figure 6-129

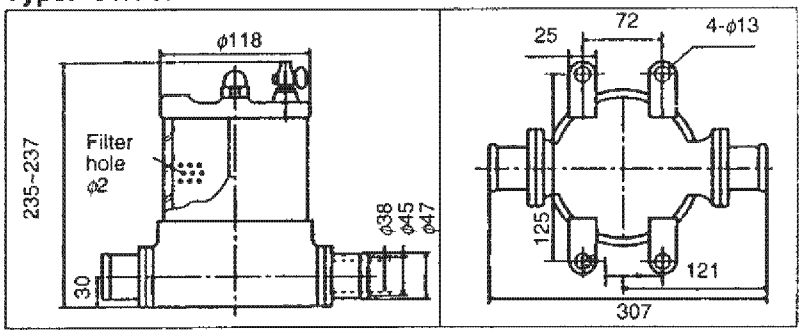
Type: SWF1. YMR Internal Code: D29795-48300 unit: mm



Type: SWF2. YMR Internal Code: D19171-48300



Type: SWF3. YMR Internal Code: D27676-48100



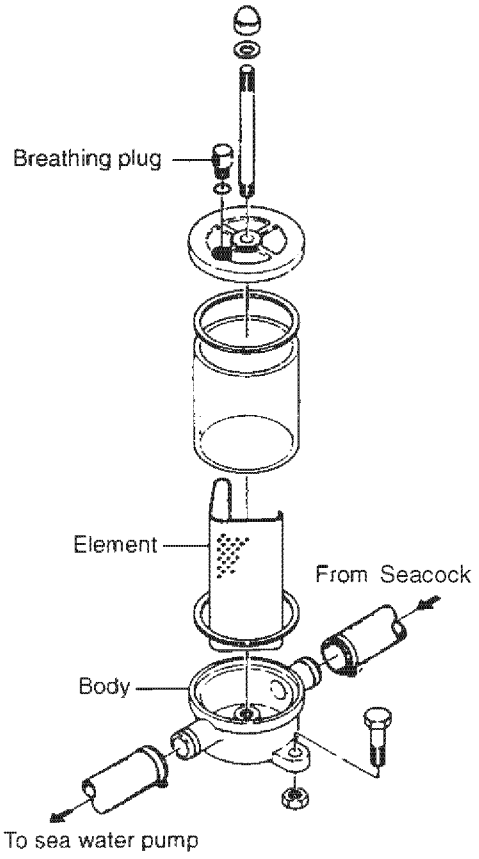


Figure 6-130

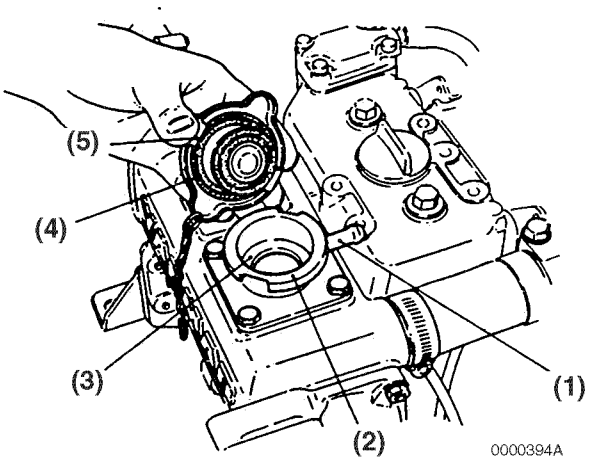
Closed Cooling System

Filler Cap (Pressure Cap) and Coolant Recovery Tank

Filler Cap Construction

The filler cap is installed on the closed cooling supply port and is equipped with a pressure control valve. To install the pressure cap, align the locking tab and the flyneck cam and turn to tighten the cap.

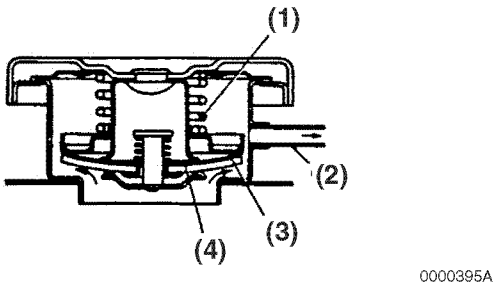
The top seal touches the flyneck tap seat while the pressure valve touches the lower seat.



1 – Overflow Pipe
2 – Top Seat
3 – Lower Seat
4 – Top Seal
5 – Locking Tab

Figure 6-131

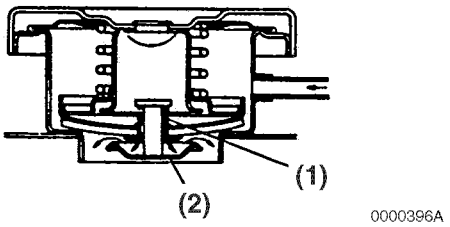
Pressure Valve Operation



1 – Pressure Valve Spring
2 – Overflow Pipe
3 – Pressure Valve
4 – Rubber Seal

Figure 6-132

Vacuum Valve Operation



1 – Vacuum Valve Spring
2 – Vacuum Valve

Figure 6-133

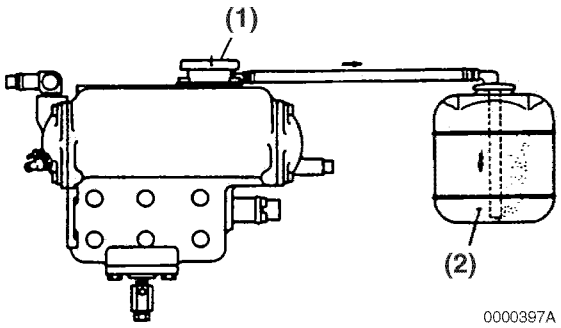
When the cooling system pressure is within the specified range or 0.9 kgf-cm^2 (12.8 psi) the pressure valve and vacuum valve are tightly seated on the valve seats. When the pressure rises, the pressure valve opens and vapor is discharged from the overflow pipe. When the water cools and pressure in the system is lower than atmospheric pressure, the vacuum valve opens and air enters the system through the overflow pipe.

To prevent coolant loss due to the pressure valve opening, the cooling system can be equipped with a coolant recovery tank.

Pressure Valve	Opens at 0.9 kgf-cm^2 (12.8 psi) G
Vacuum Valve	Opens at 0.05 kgf-cm^2 (0.711 psi) G or below

Coolant Recovery Tank Function:

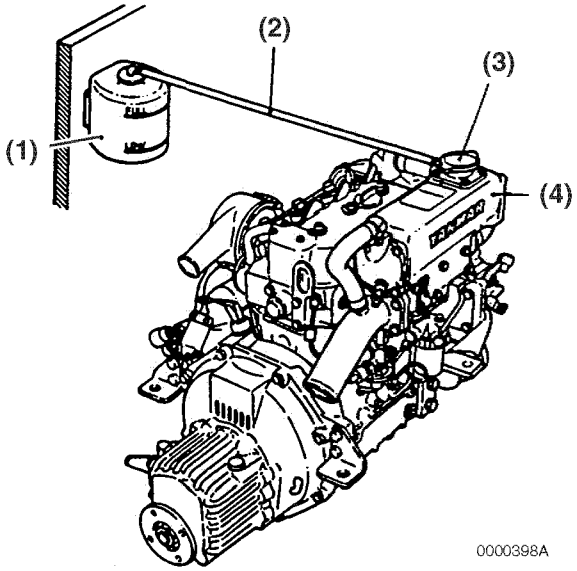
When the cooling system pressure rises above the 0.9 kgf-cm^2 (12.8 psi), the pressure valve opens and vapor is released, reducing the amount of coolant in the cooling system. The coolant recovery tank collects this vapor as it condenses. When the cooling system pressure falls below atmospheric pressure, the coolant in the coolant recovery tank is siphoned back to the main tank on the heat exchanger. Install a coolant recovery tank to allow the engine to be operated for longer periods and eliminate the need to open the filler cap on the heat exchanger.



1 – Filler Cap
2 – Coolant Recovery Tank

Figure 6-134

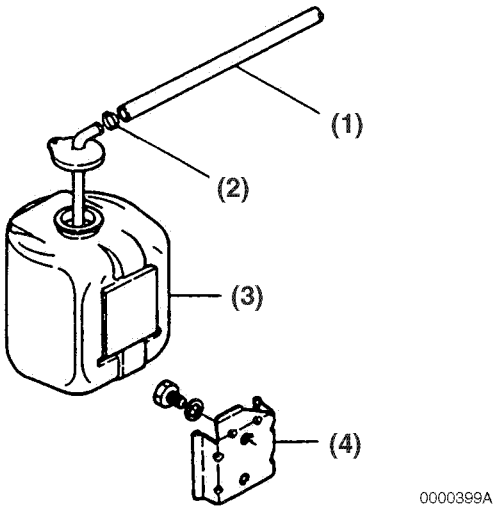
Coolant Recovery Tank Installation



1 – Coolant Recovery Tank
2 – Overflow Pipe
3 – Filler Cap
4 – Heat Exchanger Tank

Figure 6-135

1. Mount the coolant recovery tank at the same height as the heat exchanger.
2. Ensure that the overflow pipe is not damaged or leaking and the holes are not obstructed.



1 – Hose
2 – Hose Clamp
3 – Coolant Recovery Tank
4 – Bracket

Figure 6-136

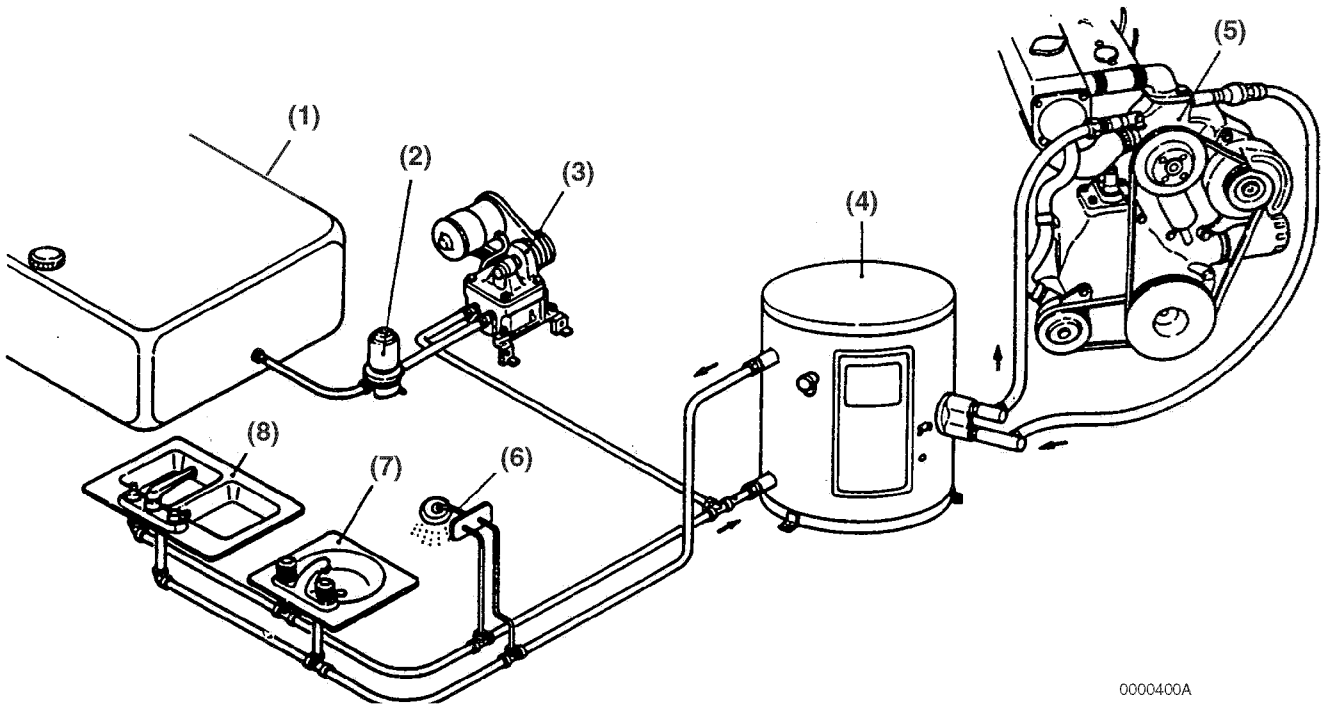
Cabin Water Heaters

The temperature of the engine coolant during operation is maintained by the engine thermostat at a constant 70 - 85°C (158 - 185°F). This heated coolant can be used to heat water for showers, wash basins and other on-board hot water needs by installing commercially available water heater tanks.

Some commercially available water heater tanks use electric heaters, liquid propane, or engine coolant as heat sources. Typically, these water heaters operate on AC shore power, on-board electric AC generator power, on-board DC battery power or liquid propane.

Figure 6-137 illustrates a typical layout for an inboard hot water supply system.

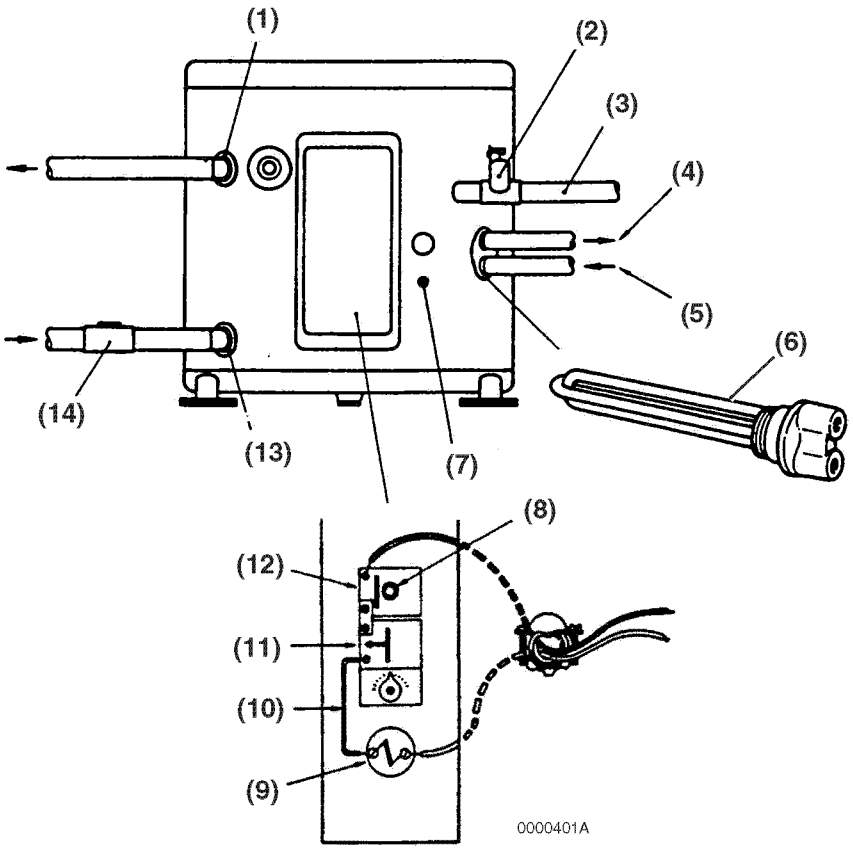
Typical On-Board Hot Water Supply System



1 – Fresh Water (Potable) Tank
2 – Filter
3 – Fresh Water Pressure Pump
4 – Water Heater Tank
5 – Engine Coolant Circulation Pump
6 – Shower
7 – Wash Basin
8 – Other On-Board Water Needs

Figure 6-137

Typical Water Heater Tank Construction

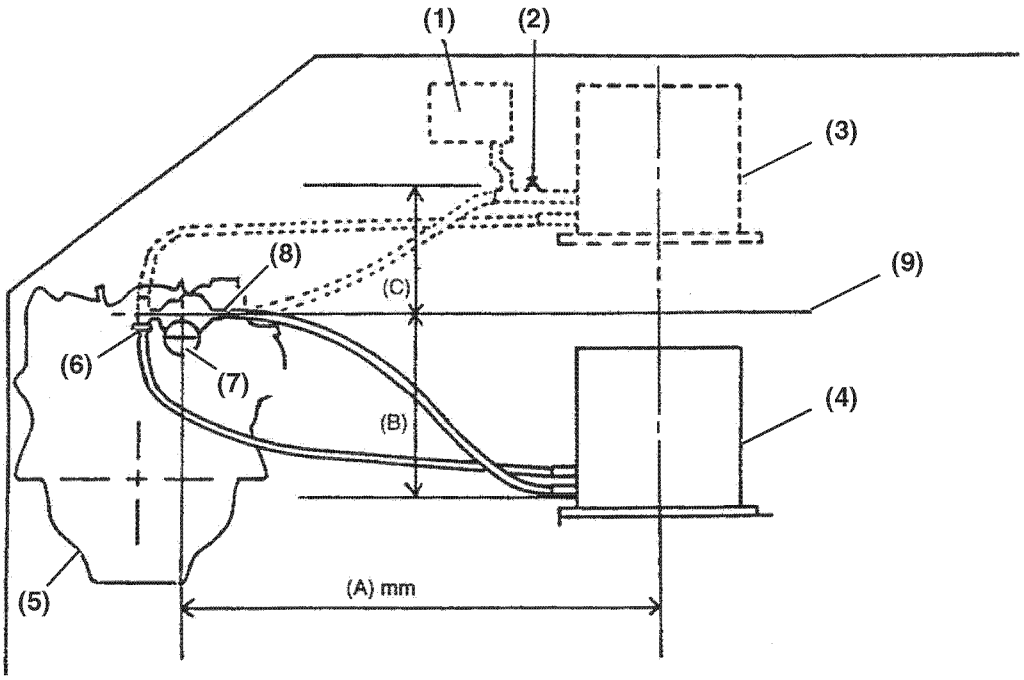


1 – Hot (Potable) Water Out
2 – Excess Pressure / Temperature Safety Valve
3 – To Overboard
4 – Coolant Return to Engine
5 – Hot Coolant from Engine
6 – Heat Exchanger
7 – Water Heater Tank
8 – Reset Button
9 – Heating Element
10 – Black Wire
11 – Thermostat
12 – High Temperature Limit Switch
13 – Cold (Potable) Water Inlet
14 – Pressure System Check Valve

Figure 6-138

Allowable Installation Position of Water Heater Tank

(A)	(B)	(C)	Running Condition
2 m (6.6 ft)	0.5 m (19.7 in.)	0.5 m (19.7 in.)	(1) Engine output: 4/4 load (2) Connect rubber hose, inner dia. f: 16 mm (5/8 in.) (3) Installed reserve tank of (C) dimension



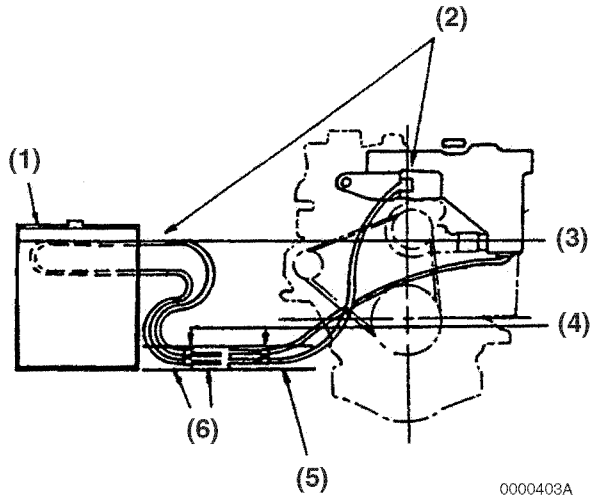
1 – Reserve Tank
2 – Air Vent Hole
3 – Water Heater - Installation Above Closed Cooling Pump Outlet Level (C)
4 – Water Heater - Installation Below Closed Cooling Pump Outlet Level (B)
5 – Engine
6 – Inlet
7 – Engine Coolant Circulation Pump
8 – Outlet
9 – Engine Coolant Outlet Level

Figure 6-139

Installation

When designing for and installing a water heater tank:

- **Avoid air locking** - The highest point in the system must be lower than the engine coolant recovery tank level. The water flow system must be designed to flow upward.
- **Prevent damage from vibration or chafing** - Piping to and from the engine must be installed with flexible connections.
- **Avoid cold weather freezing damage** - Install drain cocks or plugs at the lowest part of the piping system.
- **Prevent back-flow** - Install a check valve in the piping on the engine side to check the flow of the cooling water when the water heater is not in use.



1 – Water Heater
2 – Vent Valves (necessary to release trapped air at high points of the system)
3 – Water heater tank piping must be below this level
4 – Stainless Steel Pipe Clamps
5 – Drain Cocks necessary at lowest points of the system
6 – Clamps to engine bearers; flexible pipes to engine.
Water heater plumbing must not kink or chafe and must allow for engine vibration

Figure 6-140

- Pipes must be as short as possible with the minimum number of bends.
- **Avoid inverted "U" bends when possible** - If inverted "U" bends must be used, they must be fitted with vent valves or plugs to provide proper venting.
- Increase the engine's closed cooling tank capacity and the piping leading to the cooling water tank.

IMPORTANT

Where an internal piping coil is mounted horizontally in the tank, forming a series of inverted "U" bends, particular care must be paid to air venting. The engine coolant level must be rechecked several times to ensure that the total system is free of air and that the heater tank level is correct.

Note: If a water heater tank is installed, more water will be needed than can be handled by a single engine unit. A larger tank and more piping is required. Since this additional water capacity varies depending on the piping length, boat builders must measure the additional water requirements when fabricating the water heater tank piping. Insufficient cooling water could cause engine overheating.

Selection Test (at Yanmar) Water Heater Tank with Engine

Water heater capacity and dimensions for test:

Water Capacity	A in. mm	B in. mm	C in. mm	D in. mm	E in. mm	F in. mm	G in. mm
6 gal	14.0	16.188	11.125	3.125	5.75	7.50	7.75
22.7 L	35.5	41.12	28.26	7.94	14.61	19.05	19.69

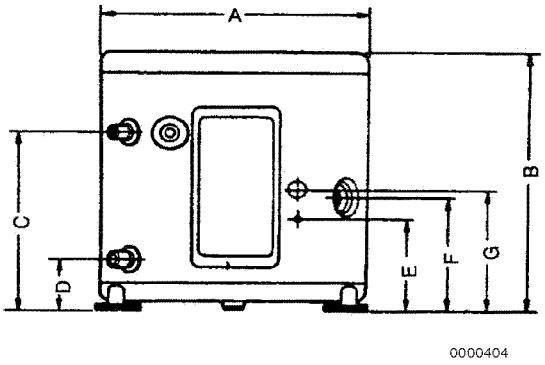


Figure 6-141

Test Conditions:

Bench test, temperature:
12.5 - 14°C (54.5 - 57.2°F)
Engine - Yanmar model:
3HMF, 22.4 kW (30 hp) @ 3400 rpm, fresh water cooling

Engine thermostat temperature:
Operating temperature 71°C (159.8°F).
Fully open temperature 85°C (185°F)
Connecting pipe for engine to water heater:
Engine outlet: Inner diameter ø11 mm, Length: 2 m
Engine inlet: Inner diameter ø13 mm, Length: 2 m

Test Data

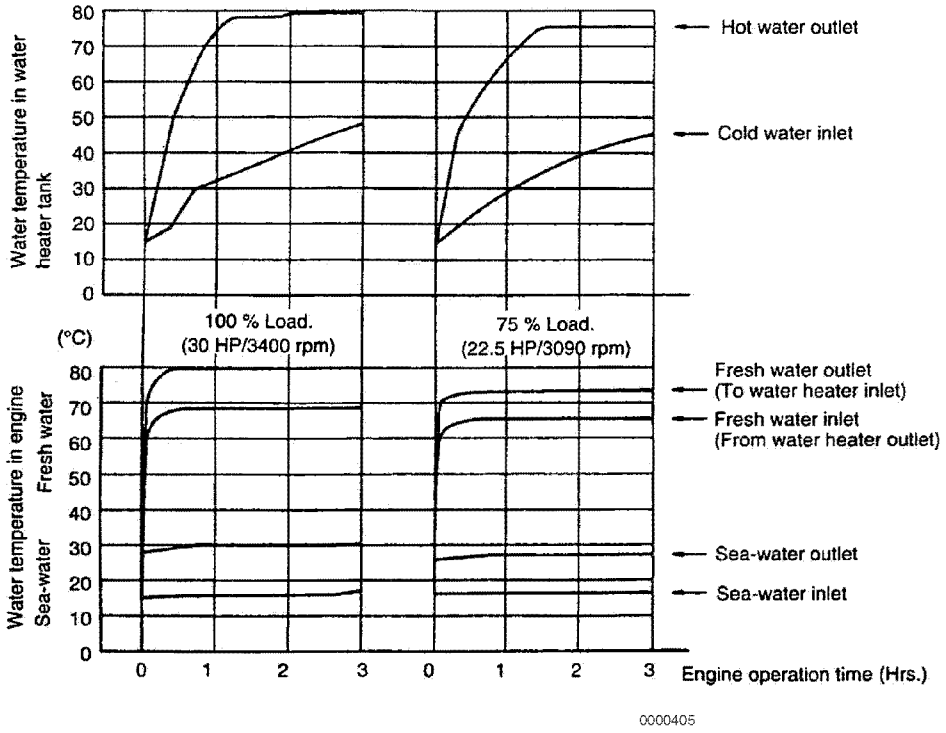


Figure 6-142

LUBRICATION SYSTEM

⚠ WARNING

BURN HAZARD!

- If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.
- ALWAYS wear eye protection.
- Failure to comply could result in death or serious injury.

0000011en

CAUTION

- Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.
- Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.
- NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.
- NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

0000005en

CAUTION

- NEVER overfill the engine with engine oil.
- ALWAYS keep the oil level between the upper and lower lines on the oil cap / dipstick.

0000015en

CAUTION

Make sure the engine is installed on a level surface. If a Yanmar Marine Engine is installed at an angle that exceeds the specifications stated in the Yanmar Marine Installation manuals, engine oil may enter the combustion chamber causing excessive engine speed, white exhaust smoke and serious engine damage. This applies to engines that run continuously or those that run for short periods of time.

0000010enMarine

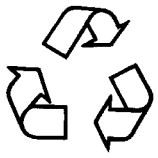
CAUTION

New Engine Break-in:

- On the initial engine start-up, allow the engine to idle for approximately 15 minutes while you check for proper engine oil pressure, diesel fuel leaks, engine oil leaks, coolant leaks, and for proper operation of the indicators and / or gauges.
- During the first hour of operation, vary the engine speed and the load on the engine. Short periods of maximum engine speed and load are desirable. Avoid prolonged operation at minimum or maximum engine speeds and loads for the next four to five hours.
- During the break-in period, carefully observe the engine oil pressure and engine temperature.
- During the break-in period, check the engine oil and coolant levels frequently.

0000011en

CAUTION



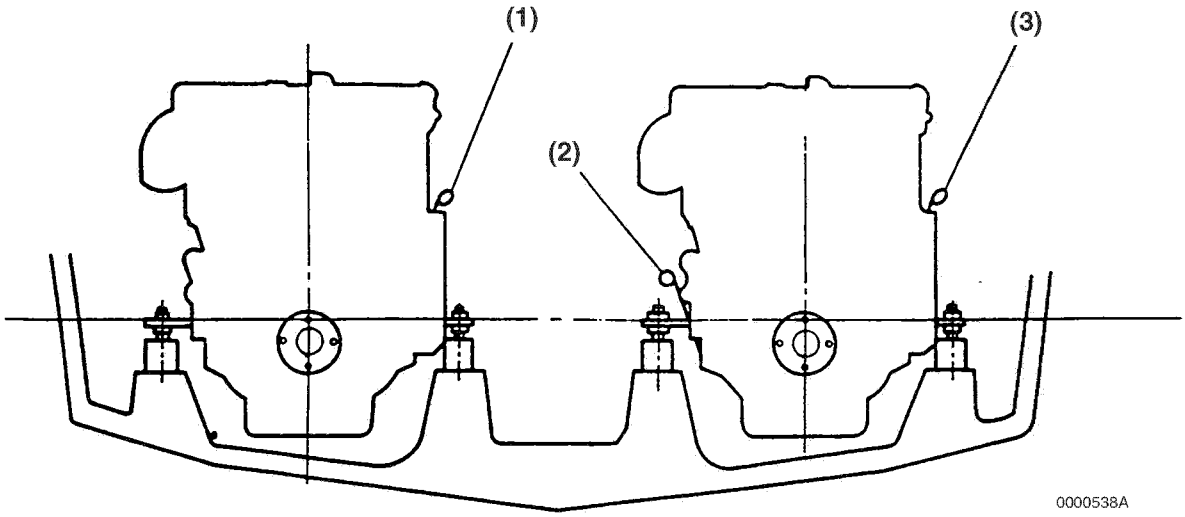
- ALWAYS be environmentally responsible.
- Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.
- NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.
- Failure to follow these procedures may seriously harm the environment.

0000013en

The purpose of the lubrication system is to reduce friction that causes wear and to cool critical parts of the engine. Heat energy is transfered to the oil and distributed through the engine. Some engines use heat exchangers to cool the engine oil.

Oil must be maintained to minimum levels and changed at regular maintenance intervals.

Some applications have opposite side dipsticks that allow easy access for twin engine installations. To use, remove the dummy plug located below the starter motor and insert the opposite side oil dipstick.

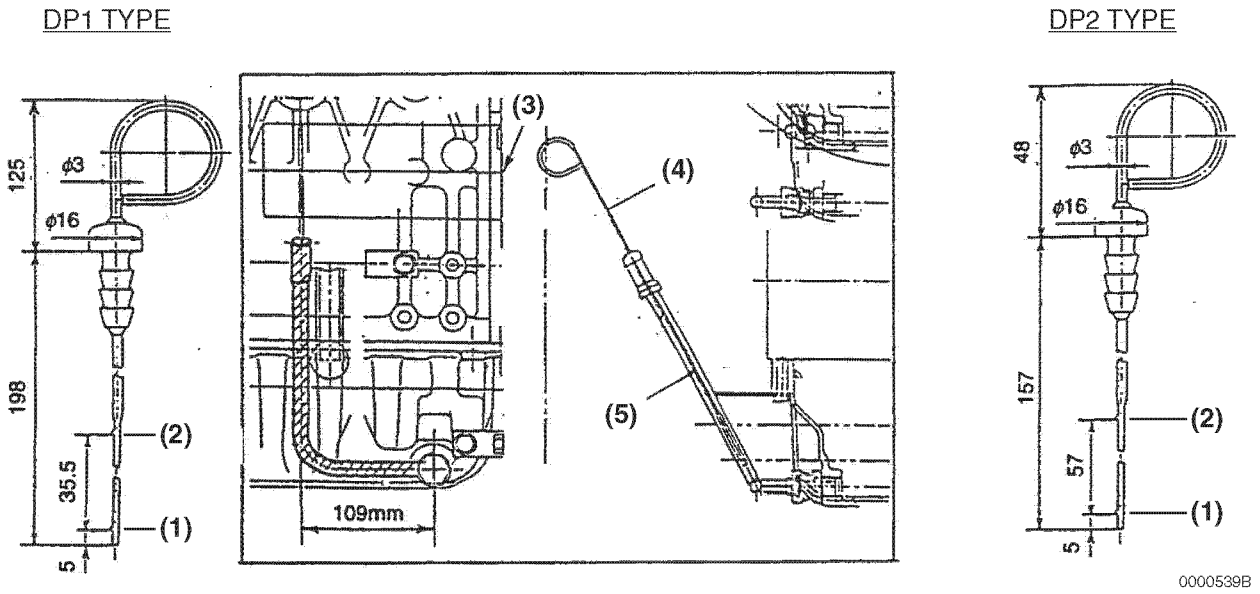


1 – Crankcase Oil Dipstick - Standard
2 – Oil Dipstick - Optional
3 – Crankcase Oil Dipstick - Standard

Figure 6-143

Note: Viewed from stern.

Type	Yanmar Part Number
DP1	D29570-34210
DP2	D19171-34110



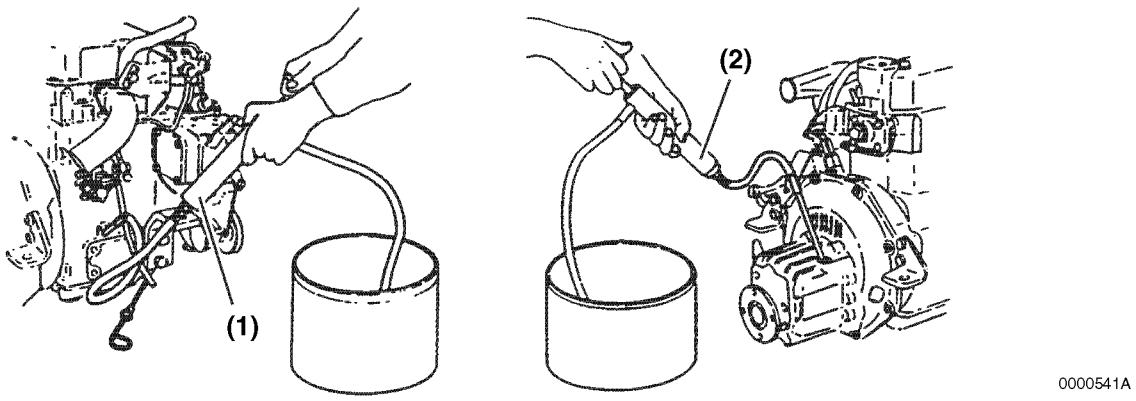
1 – Lower Limit
2 – Upper Limit
3 – Flywheel Side
4 – Dipstick
5 – Guide Tube

Figure 6-144

Draining Engine Oil

Generally, engine oil drain plugs at the bottom of the engine are not readily accessible. The same can be said of the marine gear.

Using an oil evacuation pump eliminates the need to drain oil from the drain plug.

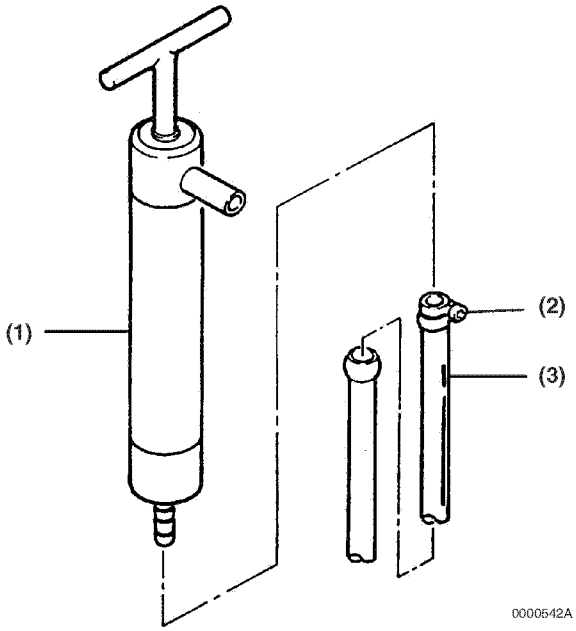


1 – Oil Evacuation Pump (Engine)
2 – Marine Gear

Figure 6-145

Piston-Type, Oil Evacuation Pump

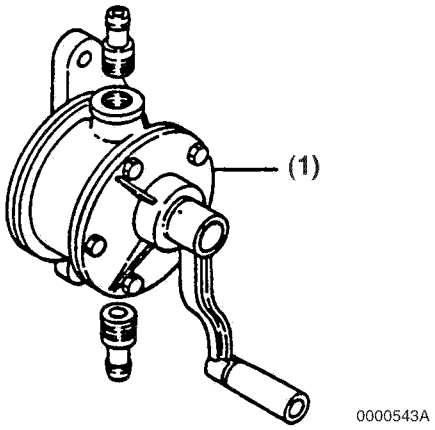
Type	Yanmar Part Number
EPP 1	D05584-39501



1 – Piston-Type Oil Evacuation Pump
2 – Hose Clamp
3 – Hose - Inner diameter ϕ15 mm (0.59 in.) Length: 1000 mm (3.28 ft)

Figure 6-146

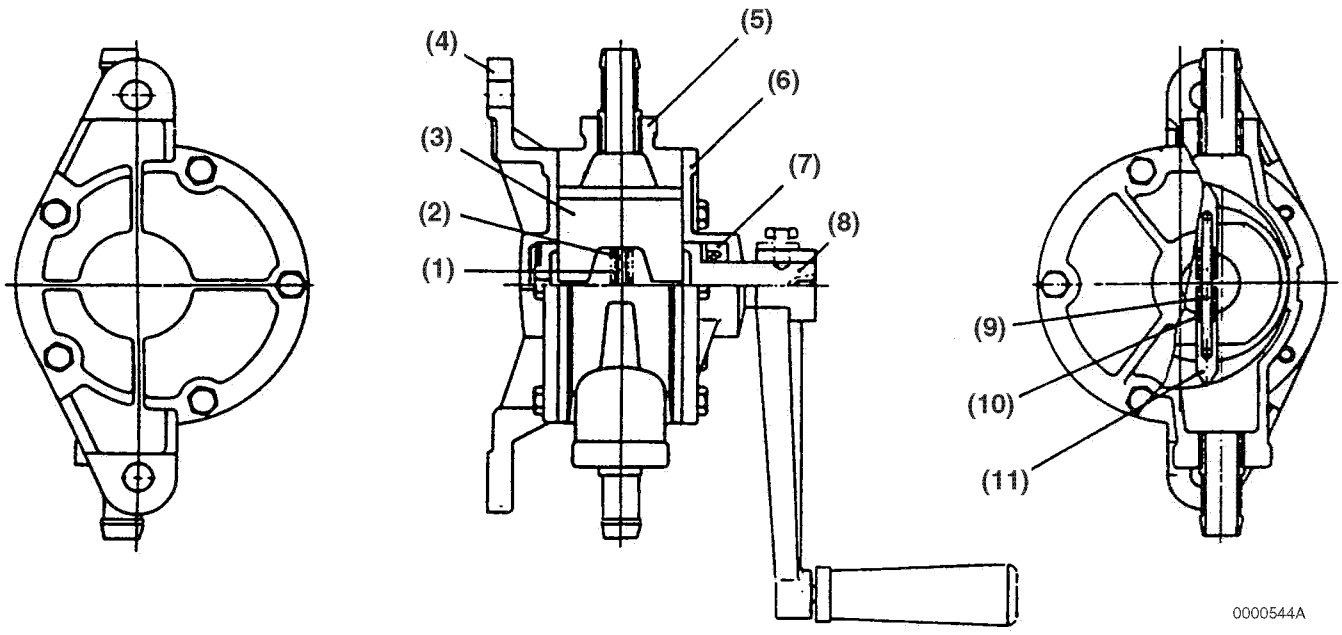
Rotary-Type, Oil Evacuation Pump



1 – Rotary-Type Oil Evacuation Pump

Figure 6-147

Type	Yanmar Part Number
EPR 1	D20130-37100
EPR 2	D27695-37210



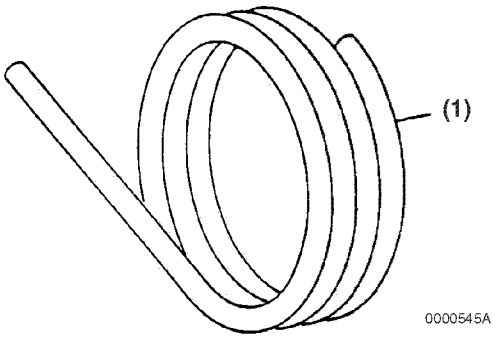
1 – Spring
2 – Spindle
3 – Vane
4 – Cover
5 – Body
6 – Cover
7 – Oil Seal
8 – Shaft
9 – Spindle
10 – Spring
11 – Vane

Figure 6-148

Specifications

Delivery capacity of one stroke	0.13 L (0.137 qt)
Delivery pressure	1.5 kgf/cm^2 or less (21.3 psi or less)
Suction head	less than 1.0 m (39.37 in.)

Rubber Hose



1 – Rubber Hose

Figure 6-149

Inner Diameter X Length	ϕ12 x 1000 mm (0.47 in. x 3.28 ft)
Yanmar Part Number	43720-001220

EXHAUST SYSTEM

⚠ WARNING

EXHAUST HAZARD!

- NEVER operate the engine in an enclosed area such as a garage, tunnel, underground room, manhole or ship's hold without proper ventilation.
- NEVER block windows, vents, or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.
- Make sure that all connections are tightened to specifications after repair is made to the exhaust system.
- Failure to comply could result in death or serious injury.

0000003en

⚠ WARNING

BURN HAZARD!

- Keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.
- Failure to comply could result in death or serious injury.

0000015en

CAUTION

For maximum engine life, Yanmar recommends that when shutting the engine down, allow the engine to idle, without load, for five minutes. This will allow the engine components that operate at high temperatures, such as the turbocharger (if equipped) and exhaust system, to cool slightly before the engine itself is shut down.

0000008en

The exhaust systems of all Yanmar pleasure boat engines are wet-type. Exhaust gas and cooling water are gathered in the exhaust / water mixing elbow (standard or optional) of the exhaust port for discharge together. Accordingly, a heat-resistant rubber hose can be used for the exhaust pipe. This permits a simple exhaust pipe layout.

Exhaust Piping System

It is necessary to arrange the piping to allow for inspection of the whole system. Also, a suitable arrangement is necessary to prevent seawater from flowing back into the engine. A water lock must be installed to prevent water remaining in the hose from flowing back to the engine side when stopping the engine or immediately after starting.

The water lock must be fixed at the lowest possible position and the hose must be tilted downward as much as possible. It is also necessary to elevate the exhaust hose at the exhaust outlet to more than 350 mm (13.77 in.) above the loading draft line.

IMPORTANT

Avoid corrosion of exhaust / water mixing elbow.

The exhaust / water mixing elbow has a partial double-pipe construction where the inner pipe is for exhaust gas and the outer pipe is for the cooling water (seawater) to flow. The exhaust and the seawater are mixed on the way to the exhaust port for discharge together.

Typical diesel engine exhaust contains the following:

- *Carbon monoxide = CO*
- *Hydrocarbon = HC*
- *Nitrogen oxide = NO_X*
- *Sulfur dioxide = SO_2*

When mixed with seawater, these gases chemically cause sulfuric acid corrosion of the exhaust / water mixing elbow, which is made of cast iron or a stainless steel alloy. ***Replace the exhaust / water mixing elbow once every two years.***

Water Lock

The water lock is used when the engine's exhaust port is located below the waterline. This device is especially useful for sailboats, which do not use their engine frequently.

The installation of a water lock does not cause a large horsepower loss due to the increase of exhaust back pressure.The use of a water lock is inappropriate for power boats, which use the engine's full output. If a water lock is installed on the exhaust piping, back pressure will increase and engine output will drop. In power boats, a high-type exhaust / water mixing elbow must be used for the piping layout to prevent the reverse flow of exhaust water.

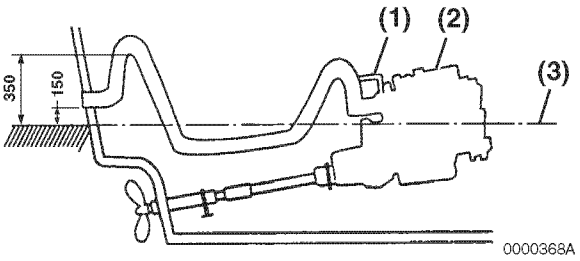
IMPORTANT

Be sure to install a drain plug or cock at the bottom of the water lock. This is to prevent possible engine damage due to the entry of remaining water into the engine's exhaust port when the hull is tilted stern side up for transportation, etc.

Exhaust Piping Layout

Cooling water / exhaust piping varies according to the hull shape and engine room position.

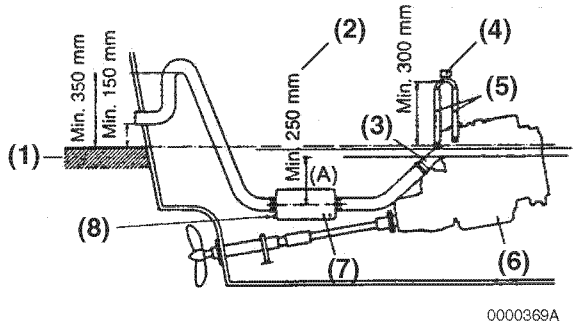
1. When the water outlet of engine **(Figure 6-150, (1))** is above the waterline:



1 – Cooling Water Outlet Pipe
2 – Engine
3 – Waterline

Figure 6-150

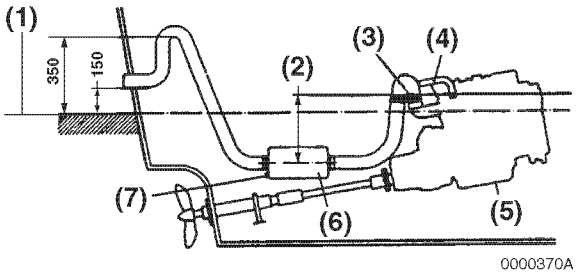
2. When the water outlet of engine is below the waterline **(Figure 6-151, (2))**, attach a vacuum valve to the exhaust / water mixing elbow of the cooling water pipe (recommended for sailboats).



1 – Waterline
2 – Below Waterline
3 – Mixing Elbow
4 – Vacuum Valve
5 – Cooling Water Pipe
6 – Engine
7 – Water Lock
8 – Drain Cock

Figure 6-151

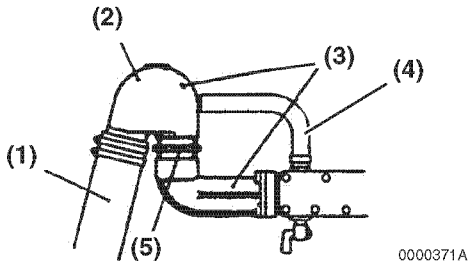
3. If the height of the cooling water outlet at the engine side is lower than the waterline, use a high-port exhaust / water mixing elbow.



1 – Waterline
2 – Engine Side Cooling Water Outlet Height
3 – Exhaust Pipe (High-Port Type)
4 – Cooling Water Pipe
5 – Engine
6 – Water Lock
7 – Drain Cock

Figure 6-152

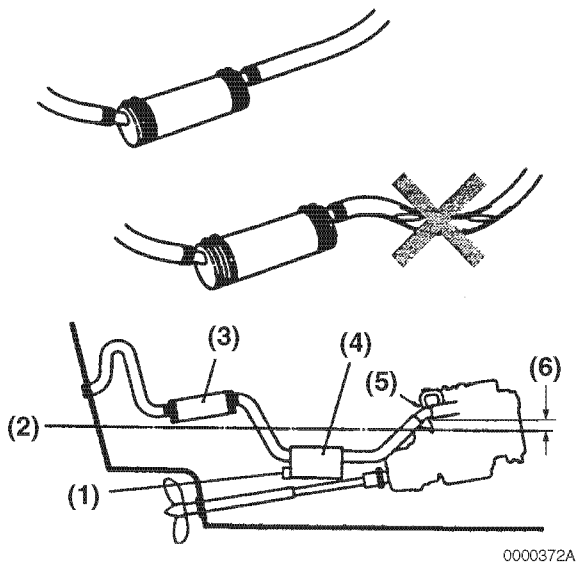
4. Wrap lagging around the water mixing elbow to prevent the engine room temperature from rising. The engine room space in pleasure boats is generally narrow, so be sure to provide lagging to prevent excessive temperature rise in the engine room and also as a safety precaution.



1 – Rubber Hose
2 – Exhaust / Water Mixing Elbow
3 – Lagging
4 – Cooling Water Hose
5 – Exhaust Pipe Riser

Figure 6-153

5. Exhaust system with water injection point **(Figure 6-154, (5))** 150 mm (5.9 in.) or more above waterline:

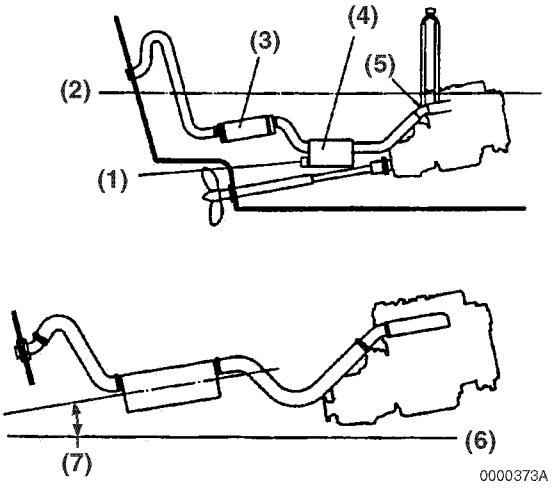


1 – Drain Cock
2 – Waterline
3 – Muffler
4 – Water Lock
5 – Water Injection Point
6 – 150 mm (5.9 in.) or greater

Figure 6-154

6. Exhaust system with water injection point **(Figure 6-155, (5))** less than 150 mm (5.9 in.) above the waterline:

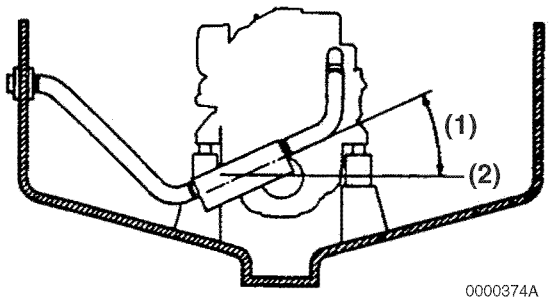
   - Fore-and-aft inclination of muffler: 5 - 7.5° **(Figure 6-155, (7))**.



1 – Drain Cock
2 – Waterline
3 – Muffler
4 – Water Lock
5 – Water Injection Point)
6 – Waterline
7 – Inclination of Muffler

Figure 6-155

7. Athwart inclination of silencer, A = 25 - 45°



1 – A **2 – Waterline**

Figure 6-156

Exhaust Back Pressure

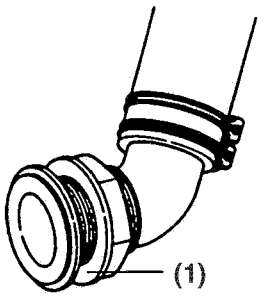
Exhaust piping which develops an excessive back pressure causes incomplete engine combustion, the emission of abnormally-colored exhaust, increased fuel consumption, engine speed (output) drop and a rise in the exhaust temperature. To prevent back pressure, observe the following points with regard to the exhaust piping:

1. Do not use a hose with a diameter smaller than that of the exhaust hose of the engine exhaust / water mixing elbow.
2. The back pressure rises when an exhaust silencer or water lock is used. Make the hose diameter at the outlet of the exhaust silencer or water lock 25 mm (1.0 in.) larger than that of the hose on the inlet side in such cases.
3. Avoid sharp bends in the exhaust piping hose.
4. Excessive rise in back pressure causes surging in turbocharged engines and this may result in damage to the turbocharger. Accordingly, do not use a water lock for turbocharged engines.

Note: When it is suspected that the exhaust piping is causing excessive back pressure, it is necessary to de-rate the engine output and select a more suitable propeller.

Scupper

1. The scuppers should be at least 150 mm (5.9 in.) higher than the loaded waterline of the boat.
2. Use seawater-resistant material for the metal fixtures of the scupper.
3. Provide complete sealing with a silicone rubber-based sealing agent at the exhaust outlet location in the hull and on the threaded parts of the outlet.

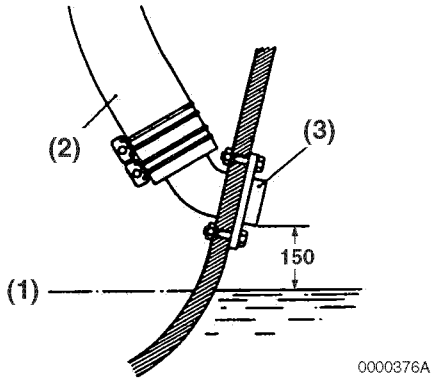


1 – Scupper

Figure 6-157

The bow and stern rise and fall during cruising. The exhaust port on the stern should be fitted to be 150 mm (5.9 in.) above the waterline during cruising.

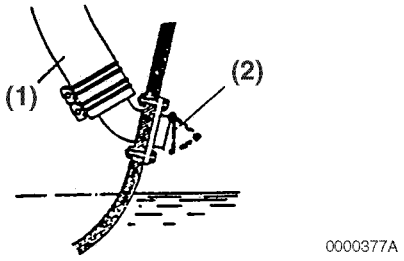
Note: When the exhaust port falls below the waterline, the back pressure rises, engine output is lowered and this causes abnormally-colored exhaust and engine trouble.



1 – Waterline
2 – Exhaust Rubber Hose
3 – Through-Hull Fitting

Figure 6-158

4. Installation of a butterfly (flapper) cover on the end of the scupper helps to prevent seawater from entering the exhaust port when the engine is stopped.



1 – Exhaust Rubber Hose
2 – Flapper Cover

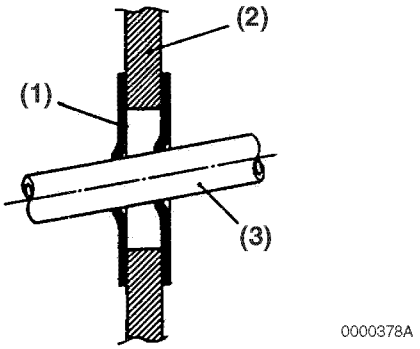
Figure 6-159

Precautions for Exhaust Piping

1. Use an all-weather, heat-resistant, oil-proof rubber hose.

   When the hose passes through the cabin or other section where people enter or exit, use a hose with high durability.

2. When bending the hose, bend it in a large curve so that the hose diameter is not altered.
3. Keep the hose away from substances which may damage or distort it.
4. When the hose goes through a bulkhead or other walls, protect the hose from distortion or friction damage.
5. Attach the hose in a way which allows for the flexible movement of the hose during engine vibration.



1 – Flexible Protection Material
2 – Bulkhead or Wall
3 – Exhaust Rubber Hose

Figure 6-160

6. Use at least two non-overlapping clamps at each end.

Measuring Engine Output (Exhaust Temperature)

A thermometer, thermocouple and tachometer must be used to take this measurement.

Prior to measurement, be sure to measure the ambient temperature (open air, engine room and seawater) and the temperatures of the engine oil and fresh cooling water.

For exhaust temperature values, refer to the Engine Data sheet for each engine.

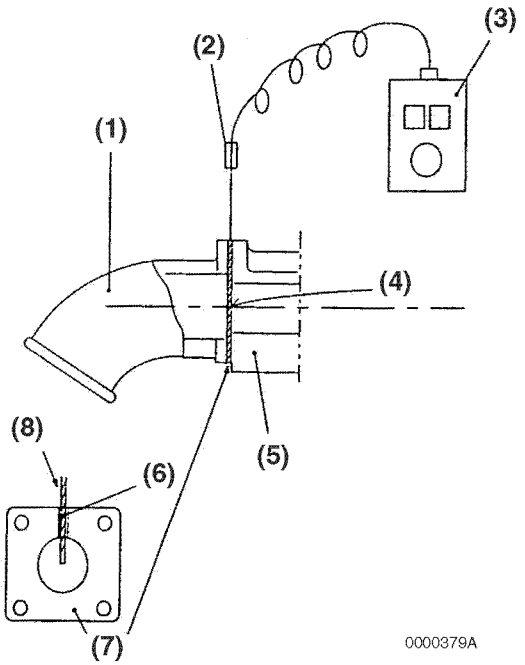
These values are based on the atmospheric conditions of the Yanmar Industrial Standard (YIS).

Note: Keep the top end of the thermocouple in the center of the exhaust port or the temperature measurements will fluctuate.

Naturally Aspirated Engines

1. Make a slit in the gasket packing installed between the exhaust / water mixing elbow and exhaust manifold. Insert the thermocouple into the slit and fasten the tip in the center of the exhaust port.

Note: Use a thermocouple with a cable diameter of less than 2.0 mm. If larger than 2.0 mm, more than two pieces of gasket packing are required.



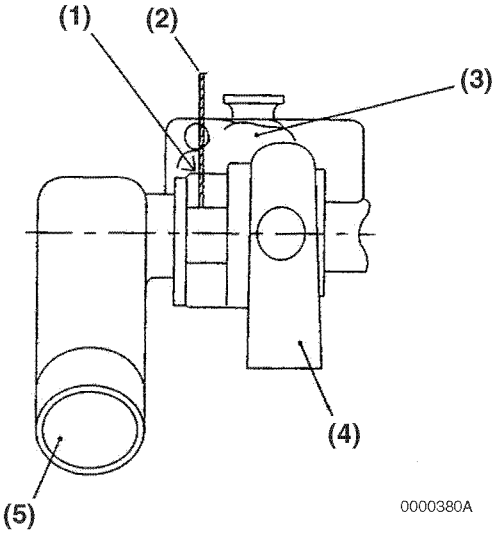
1 – Exhaust / Water Mixing Elbow
2 – Thermocouple
3 – Thermometer
4 – Center Line
5 – Exhaust Manifold
6 – Slit
7 – Gasket
8 – Thermocouple

Figure 6-161

2. Start the engine. Measure the engine speed and exhaust temperature at 1/4, 1/2, 3/4, 4/4 and 11/10 of maximum loads.

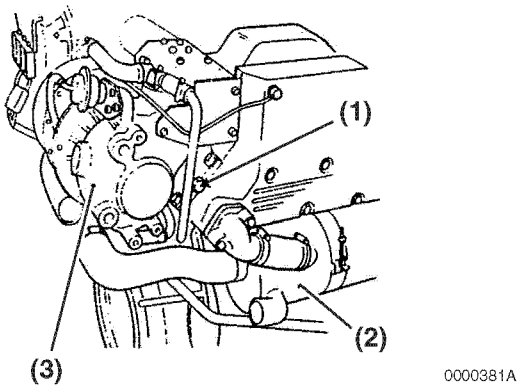
Turbocharged Engine

1. Remove the blind plug, PF 1/8 **(Figure 6-163, (1))** or PF 3/8 **(Figure 6-162, (1)),** located between the exhaust manifold and turbocharger inlet, insert the thermocouple, and fasten the tip in the center of the exhaust port.
2. Start the engine. Measure the engine speed and exhaust temperature at 1/2, 1/4, 1/2, 3/4 and 11/10 of maximum loads.



1 – Blind Plug, PF 3/8
2 – Thermocouple
3 – Exhaust Manifold
4 – Turbocharger
5 – Exhaust / Water Mixing Elbow

Figure 6-162



1 – Blind Plug, PF 1/8
2 – Heat Exchanger
3 – Turbocharger

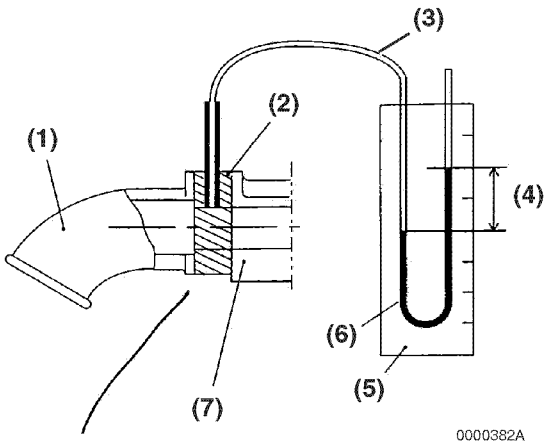
Figure 6-163

Measuring Exhaust Back Pressure

If not test port is provided, it is necessary to prepare a spacer for the manometer before measuring the exhaust back pressure. When a manometer is not available, install a vinyl hose and measure the water level difference with a scale.

Naturally Aspirated Engine

1. Install the spacer for the manometer between the exhaust / water mixing elbow and exhaust manifold.



1 – Exhaust / Mixing Elbow
2 – Spacer
3 – Vinyl Hose
4 – Water Level Difference (mmAq or in.Aq)
5 – Manometer
6 – Water
7 – Exhaust Manifold

Figure 6-164

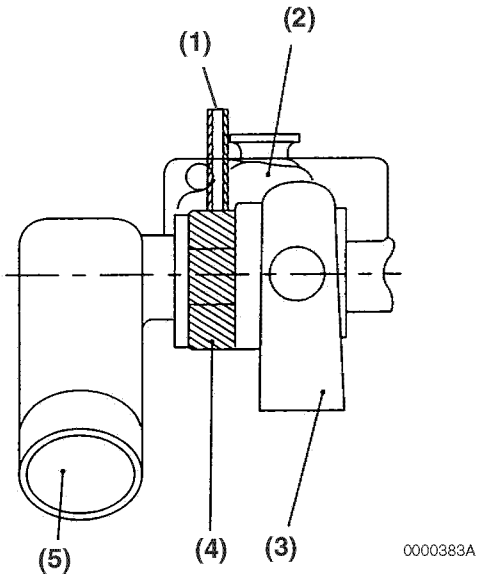
2. Connect the vinyl hose of the spacer to the vinyl hose of the manometer at one side and pour water into the hose.
3. Start the engine, raise the load gradually and measure the back pressure. The water level difference of the manometer hose shows the back pressure.

IMPORTANT

The fitting at the manifold end of the hose of the spacer must be heat-resistant.

Turbocharged Engine

1. Install the spacer for the manometer between the exhaust / water mixing elbow and turbocharger. Follow the procedure for the naturally aspirated engines.



1 – To Manometer
2 – Exhaust Manifold
3 – Turbocharger
4 – Spacer
5 – Exhaust / Water Mixing Elbow

Figure 6-165

PTO SYSTEM

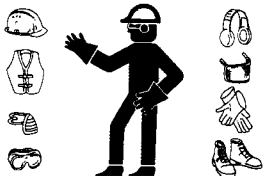
⚠ WARNING

SEVER HAZARD!

- Keep hands and other body parts away from moving / rotating parts such as the flywheel or PTO shaft.
- Wear tight fitting clothing and keep your hair short or tie it back while the engine is running.
- Remove all jewelry before you operate or service the engine.
- NEVER start the engine in gear. Sudden movement of the engine and / or vessel could cause death or serious personal injury.
- NEVER operate the engine without the guards in place.
- Before you start the engine make sure that all bystanders are clear of the area.
- Keep children and pets away while the engine is operating.
- Check before starting the engine that any tools or shop rags used during maintenance have been removed from the area.
- Failure to comply could result in death or serious injury.

0000002enMarine

⚠ WARNING



EXPOSURE HAZARD!

- **Wear personal protective equipment such as gloves, work shoes, eye and hearing protection as required by the task at hand.**
- **NEVER wear jewelry, unbuttoned cuffs, ties or loose-fitting clothing when you are working near moving / rotating parts such as the cooling fan, flywheel or PTO shaft.**
- **ALWAYS tie back long hair when you are working near moving / rotating parts such as a cooling fan, flywheel, or PTO shaft.**
- **NEVER operate the engine while wearing a headset to listen to music or radio because it will be difficult to hear the alert signals.**
- **Failure to comply could result in death or serious injury.**

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⚠ WARNING

ENTANGLEMENT HAZARD!

- **Stop the engine before you begin to service it.**
- **NEVER leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.**
- **If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving / rotating parts.**
- **Failure to comply could result in death or serious injury.**

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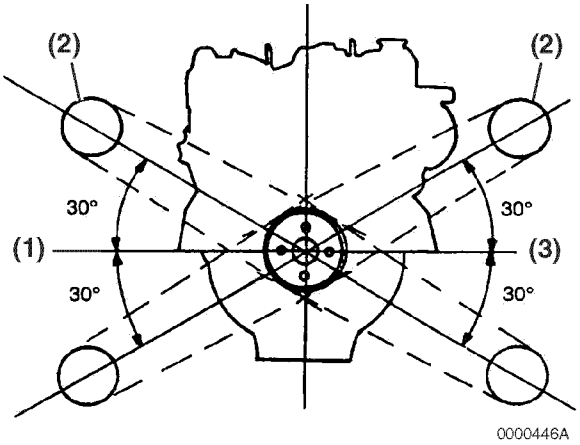
When operating a generator, pump or compressor using the power from the power take-off (PTO) crankshaft pulley on the front side (i.e., non-marine gear side) of marine propulsion engines, be sure to observe the following precautions:

General Precautions for Front PTO

1. The horsepower required to drive the machinery must be within the allowable output of the engine's front PTO.
2. Pulleys and other rotating parts must be balanced.
3. Use light material (aluminum, etc.) parts for the pulleys and other rotating parts.
4. In belt drive systems, the belt tension must be adjustable.
5. The alignment and surface run-out between the engine's PTO crankshaft pulley and the driven machinery must be within the allowable values.

6. In belt drives, keep the crankshaft pulley within 30° for both starboard and port operation **(Figure 6-166)**. When driving machinery at both starboard and port sides concurrently, keep this angle within 15°.



1. Starboard
2. Pulley
3. Port

Figure 6-166

7. Use the following formula to obtain the engine side pulley diameter. Pay careful attention to the thread hole size and the pitch circle diameter (PCD) of the crankshaft pulley face. Refer to the Engine Outline Drawing for the thread hole diameter and PCD.

Engine Side Pulley Diameter

$$\text{Engine Side Pulley Dia.}(D) = \frac{\text{Machinery rpm}(R) \times \text{Machinery Pulley Dia.}(d)}{\text{Engine rpm}(N)}$$

D : Engine side pulley diameter mm
R : Machinery speed rpm
d : Machinery pulley diameter mm
N : Engine speed rpm

Note: Pulley ratio within 3:1

Front PTO Drive System

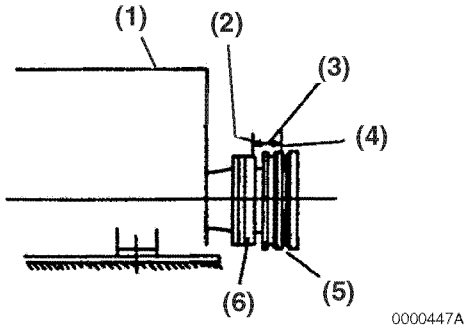
The front PTO drive systems of most marine propulsion engines belong to the following types (A-Types and D-Types). The criteria for selecting a specific drive system are:

1. Engine horsepower, usable front PTO horsepower, and the required horsepower of the driven machine
2. Engine room space
3. Engine installation (flexible engine mount or direct engine mount)

IMPORTANT

For flexible engine mount installations, drive systems are recommended. When using these drive systems, however, the conditions for use must be strictly observed. Misjudgment of (1) and (3) above could cause serious engine trouble, such as damaging the crankshaft.

A-Type - Side-Pull Belt Drive System

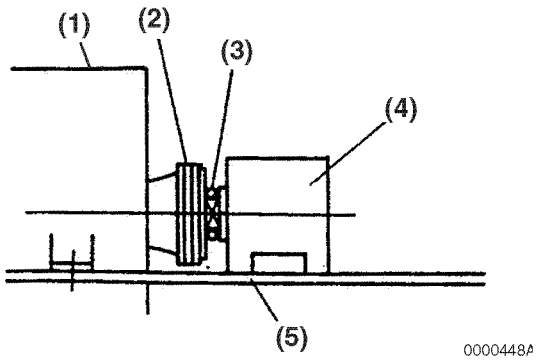


1 – Engine
2 – Face of Crankshaft Pulley
3 – Overhang (L)
4 – V-Pulley Center
5 – V-Pulley
6 – Crankshaft Pulley

Figure 6-167

Note: Overhang (L) varies depending on engine models. Strictly adhere to the overhang (L) specifications for each model. Surface run-out: 0.2 mm (0.008 in.) or less.

D-Type - Direct Coupling to Machinery Using Flexible Coupling

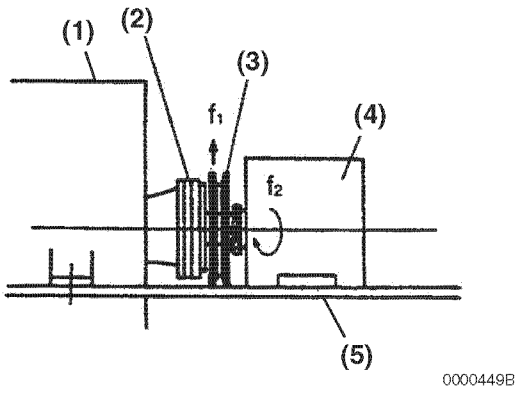


1 – Engine
2 – Crankshaft Pulley
3 – Flexible Coupling
4 – Machinery
5 – Plate (Securely Fastened)

Figure 6-168

Note: Alignment must be within 0.2 mm (0.008 in.).

D-Type - Direct Coupling with Belt Combination Drive



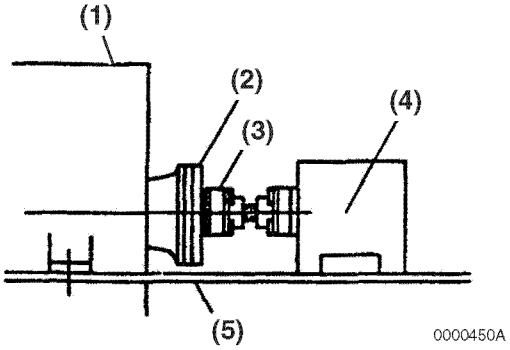
1 – Engine
2 – Crankshaft Pulley
3 – V-Pulley
4 – Machine
5 – Plate (Securely Fastened)

Figure 6-169

Note:

1. Maximum take-off output: $f_1 + f_2$.
2. Alignment: 0.05 mm (0.002 in.) or less.
3. Surface run-out: 0.2 mm (0.008 in.) or less.

D-Type - Direct Coupling to Machinery Using Flexible Joint

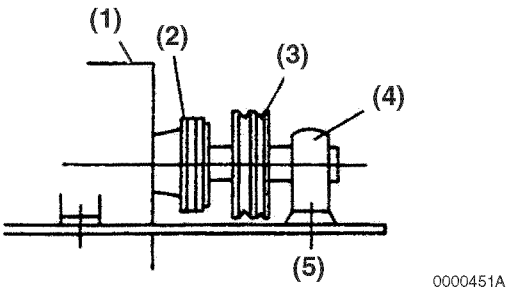


1 – Engine
2 – Crankshaft Pulley
3 – Flexible Joint
4 – Machinery
5 – Plate (Securely Fastened)

Figure 6-170

Note: Alignment must be within 0.2 mm (0.008 in.). This is dependant, however, on the alignment capacity of the flexible coupling.

D-Type - Belt Drive Using One Outside Bearing

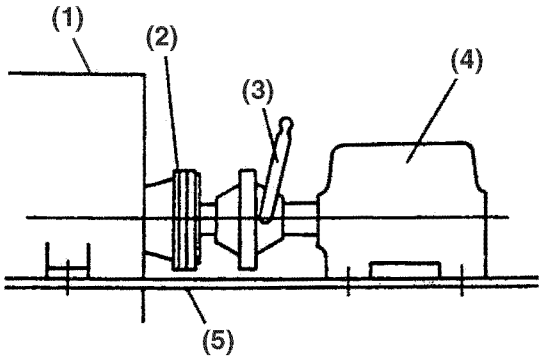


1 – Engine
2 – Crankshaft Pulley
3 – V-Pulley
4 – Bearing
5 – Plate (Securely Fastened)

Figure 6-171

Note: Alignment must be within 0.05 mm (0.002 in.).

D-Type - Direct Coupling to Driven Machinery without Belt Drive

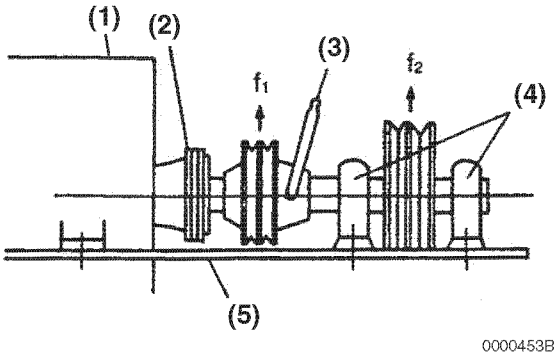


1 – Engine
2 – Crankshaft Pulley
3 – Clutch
4 – Driven Machine (Generator, Pressure Pump, etc.)
5 – Plate (Securely Fastened)

Figure 6-172

Note: Alignment must be within 0.1 mm (0.004 in.).

D-Type - Belt Drive Using Two or More Outside Bearings



1 – Engine
2 – Crankshaft Pulley
3 – Clutch
4 – Bearings
5 – Plate (Securely Fastened)

Figure 6-173

Note:

1. Maximum take-off output: $f_1 + f_2$.
2. f_1 must be less than output possible with A-type system.
3. Alignment: 0.05 mm (0.002 in.) or less. Surface run-out: 0.2 mm (0.008) or less.

Conditions of Use for Front PTO When the Engine Has Vibration-Proof Rubber Mounts

Note: All models of Yanmar pleasure craft-use marine diesel engines with flexible engine mounts.

The vibration-proof flexible mounts attached to Yanmar engines cannot be used for installing the engine and the driven machine on the common bed. The Yanmar vibration-proof flexible mount is manufactured for the weight and vibration of the engine unit and the hull vibration as tested during sea trials. Use of the engine's front PTO increases the weight of the common bed and driven machine, and the driven machine's vibrations are added. Accordingly, the vibration-proof flexible mounts attached to Yanmar engines will not provide enough protection. Purchase suitable vibration-proof flexible mounts locally.

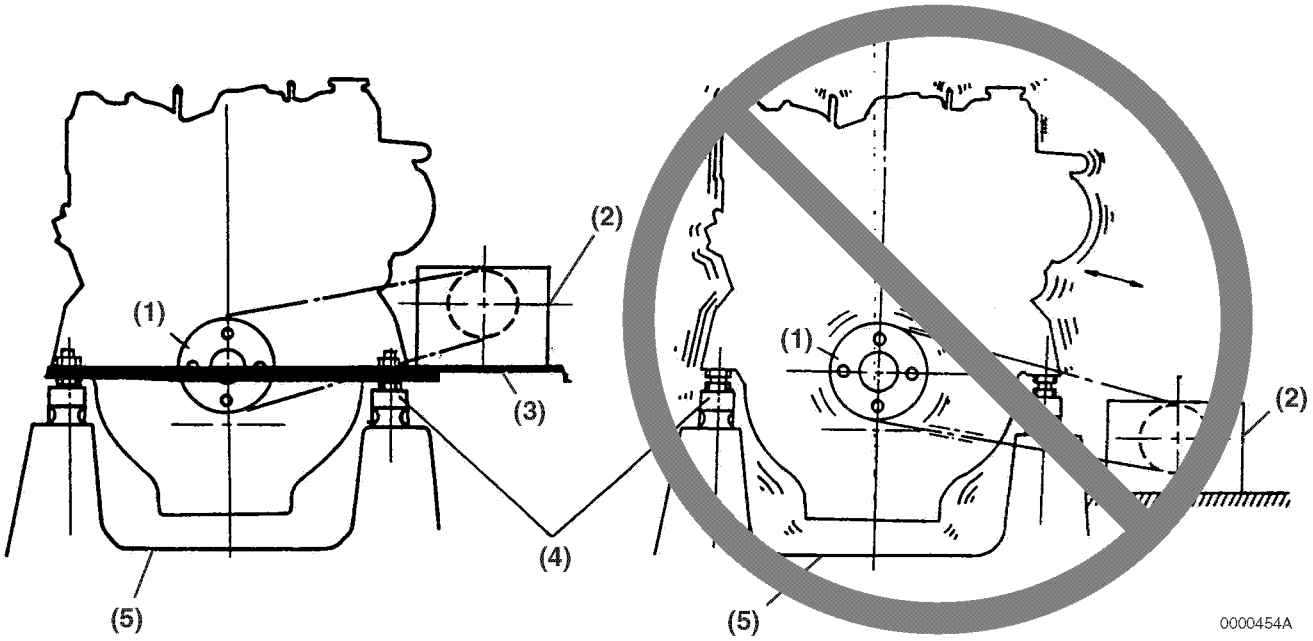
Front PTO: Side-pull belt drive system engine: vibration-proof mounting

Machine: Direct mounting on hull

When using the front PTO of the engine with flexible mounts, install both the engine and the driven machine on the common bed. Install the common bed on flexible mounts.

If only the engine is installed on the flexible mounts and the engine drives the machine via its front PTO, amplitudes will develop. These amplitudes will be transmitted from the engine's front pulley to the driven machine and then to the hull, causing the following problems:

- Increased hull vibrations
- Damage to vibration-proof flexible mounts
- Breaking of crankshaft
- Crankshaft bearing damage



1 – Front Pulley
2 – Machinery on the Common Bed
3 – Common Bed
4 – Flexible Mounts
5 – Engine Bed

Figure 6-174

Note: Front PTO: Side-pull belt drive system
Engine: Vibration-proof mounting
Machine: Direct mounting on hull

Criteria for Selecting Vibration-Proof Flexible Mounts Locally

The positions for vibration-proof flexible mount installation and the engine feet are determined by calculating the center of gravity of the engine. When the engine's front PTO is used, however, the loads of the common bed and the driven machine are added to the engine load. Also, the center of gravity of the engine varies according to the common bed shape and the installation position of the driven machine.

Where possible, it is recommended to determine the center of gravity by setting the driven machine on the common bed with the engine installed and to install the vibration-proof flexible mounts where they are actually needed.

In practice, this is extremely difficult for boat builders as it necessitates modifications to the engine bed. In such cases, Yanmar has to prepare vibration-proof flexible mounts with the equivalent spring constant to the compression ratio of the vibration-proof flexible mounts under the engine's static load and then measure the hull vibrations in a boat test.

It has been verified in hull vibration tests that when the resonance point appears as a large vibration in the engine's service speed range, using soft vibration-proof flexible mounts with a lower spring constant moves the resonance point to a lower speed range, while using hard vibration-proof flexible mounts with a high spring constant makes the resonance point rise to a higher speed range.

When using vibration-proof flexible mounts with a low spring constant to lower the resonance point speed, be sure to fully check the durability of the vibration-proof flexible mounts, vibration amplitude and thrust load at the time of engine starting.

Torsional Vibration

In addition to the vibrations caused by the engine torque, torsional vibrations cause additional twisting of the crankshaft and external shafting.

Excessive torsional vibrations can cause high stresses leading to failure of these components. It is necessary to ensure that the characteristics of the total system (i.e., engine, flywheel, marine gear, propeller shaft and propeller, and front end PTO drive) are such that excessive torsional vibration stresses will not occur. Fortunately, unless a very long propeller shaft, heavy couplings, propeller or massive front end PTO drive are used, torsional vibration problems are unlikely to occur in the normal speed range. On six- and eight-cylinder engines a viscous type damper is fitted to the crankshaft pulley and effectively “detunes” the system, reducing the amplitude of vibrations and the resulting stresses in the crankshaft, etc.

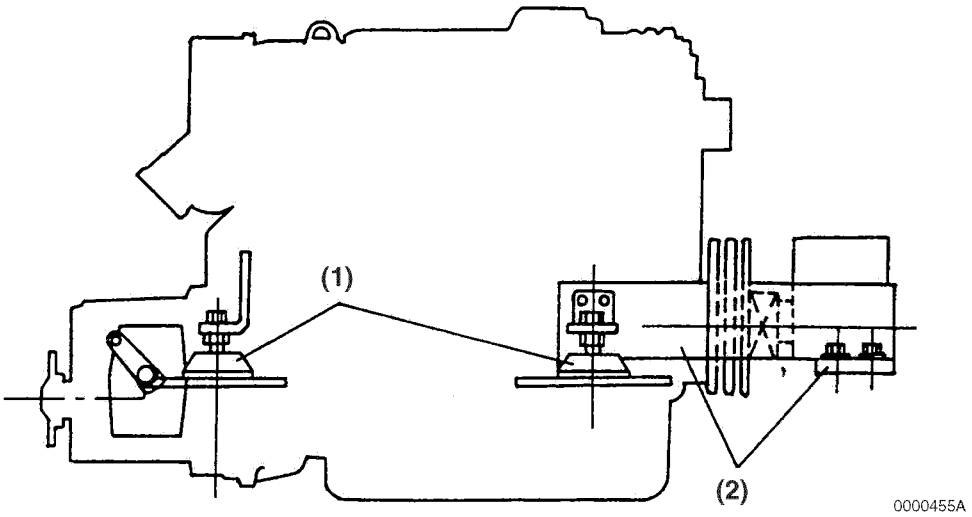
A calculation to check the probability of torsional vibration problems can be made if full details of the external shafting, etc. can be provided.

Information required is:

1. Length, diameter and material of shaft.
2. Detailed drawings of coupling with stiffness values. When the drawings are not sufficiently detailed for the moment of inertia to be calculated, this information should be obtained from the manufacturer.
3. Moment of inertia of propeller (including entrained water).
4. Detailed drawings, stiffness value and moment of inertia (if this cannot be readily calculated from the drawings) for any driven components at the front end (pump, generator, winches and clutch or gearbox, if fitted to the front end).

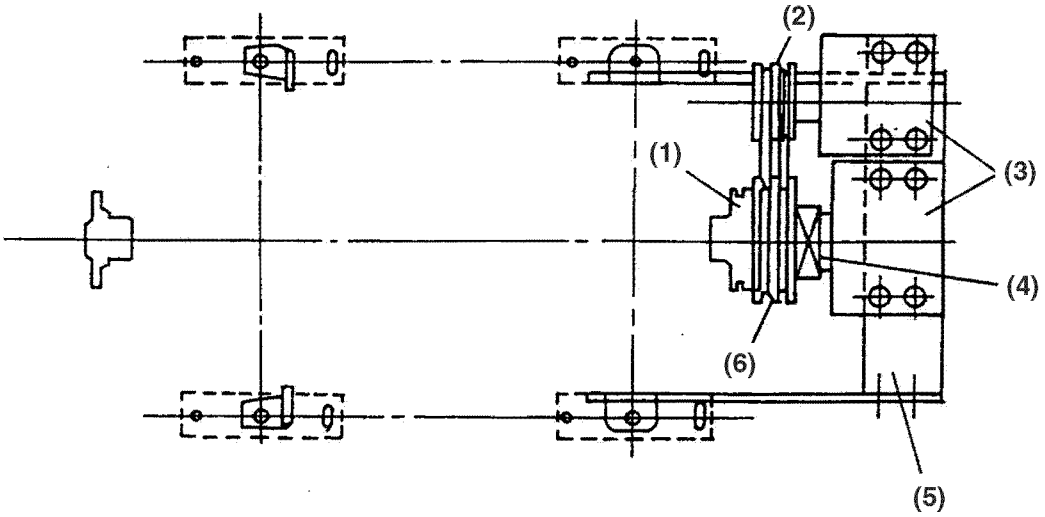
Note: Any Yanmar part used in a front end PTO drive or special propeller shaft drive, etc. should be identified by a part number.

EXAMPLE: Front PTO Drive System Using Common Bed



1 – Special Type Engine Flexible Mount
2 – Common Bed

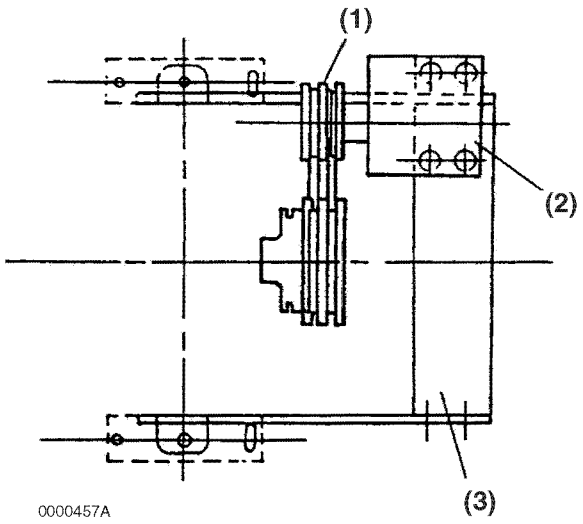
Figure 6-175



1 – Crankshaft Pulley
2 – V-Pulley
3 – Machinery
4 – Flexible Coupling
5 – Common Bed
6 – V-Pulley

Figure 6-176

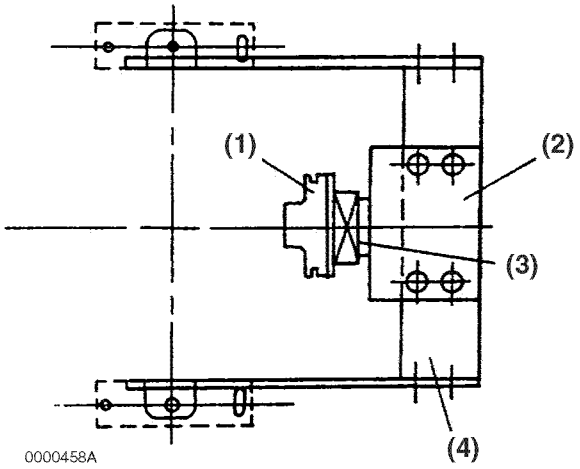
Side-Pull Driven System



1 – V-Pulley
2 – Machinery
3 – Common Bed

Figure 6-177

Direct Driven System



1 – Crankshaft Pulley
2 – Machinery
3 – Flexible Coupling
4 – Common Bed

Figure 6-178

Horsepower Required for the Front PTO Drive Machinery

Use the following formula to decide the capacity of typical front PTO machinery with in the engine's allowable horsepower.

Required Horsepower for Hydraulic Pumps (L_p)

$$L_p = \frac{P_p \times Q_p}{450 \times \eta_p}$$

$$hp = \frac{P_p \times Q_p}{612 \times \eta_p} kw$$

L_p	:	Required horsepower for hydraulic pumps	kW
η_p	:	Total power efficiency	%
P_p	:	Pump discharge pressure	kgf-cm^2
Q_p	:	Pump discharge volume	L/min

$$Q_p = \frac{qp \times N \times \eta_v}{1000} L/min$$

q_p	:	Volume	cc/rev
η_v	:	Volume efficiency	%
N	:	Pump speed	rpm

Note: To obtain the values for p and v, either refer to the performance curves of the pump or contact the pump manufacturer. The pump efficiency and volume efficiency totals differ depending on the pump manufacturer.

Horsepower (hp) Required for Generators

Formula generator capacity, kVA rating:

$$hp = \frac{kVA \times \cos\theta}{0.736 \times G\eta}$$

hp	:	Horsepower required for generators	
kVA	:	Generator capacity	
cosθ	:	Power factor	80%
Gη	:	Generator efficiency	%

Note: The Gη value varies depending on the manufacturer. Contact the manufacturer for details.

Formula generator capacity, kW rating:

$$hp = \frac{kW}{0.736 \times G\eta}$$

Other Machinery

Refer to the manufacturer's catalog to obtain the horsepower required for driving other machinery or contact the manufacturer.

$$hp = H_c \times K$$

H_c	:	Horsepower required for machinery	hp
K	:	Load coefficiency	%

Key Lock-Type for Crankshaft Pulley

When using the front PTO through the crankshaft V-pulley, use a key lock-type crankshaft pulley.

The standard specification crankshaft pulley is not the key lock-type and cannot be used for front PTO. If used, the pulley and crankshaft will be damaged due to slippage.

Specifications

Type	Yanmar Part Number
VK1	D29170-21300
VK 2	D29490-21300

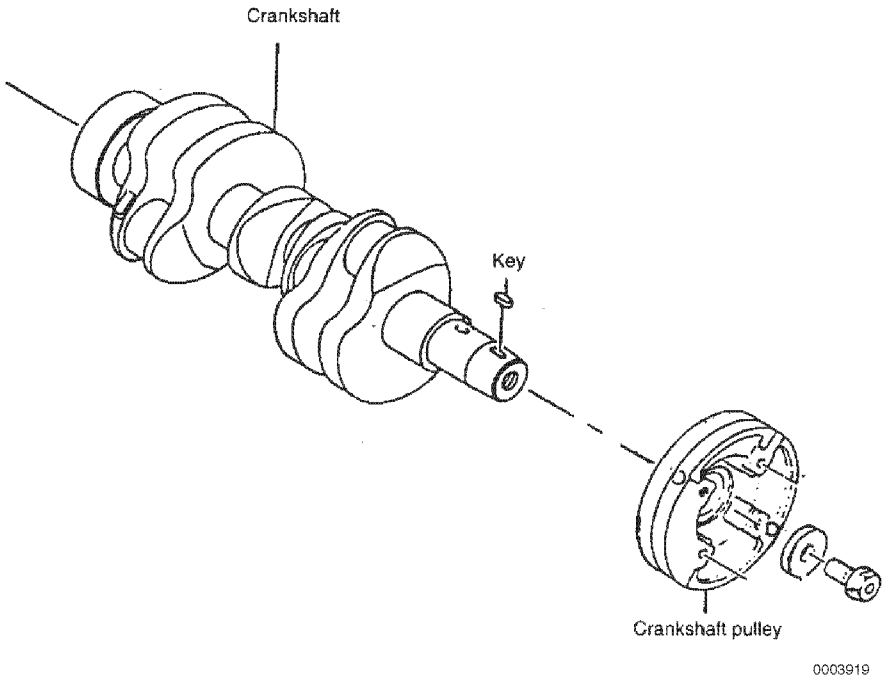


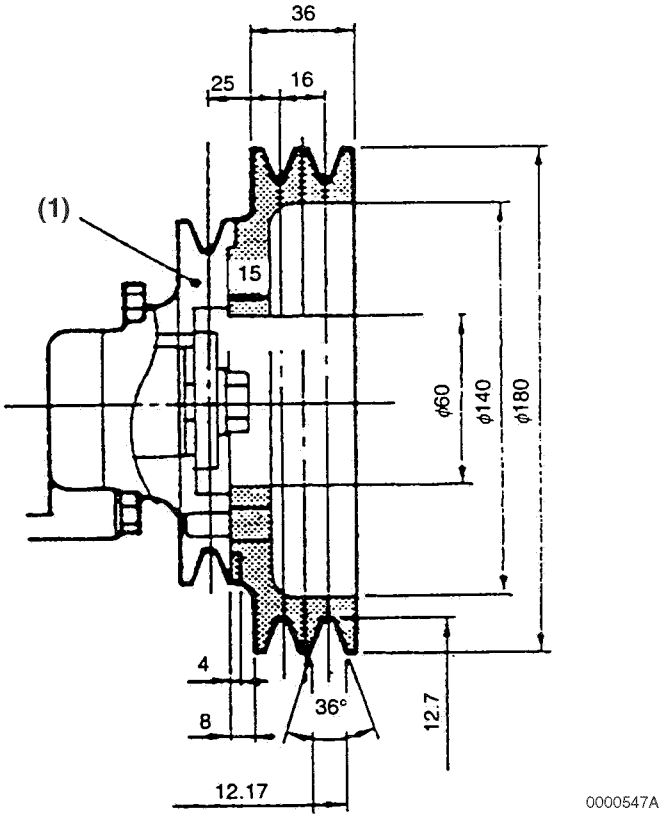
Figure 6-179

Front PTO Pulley

Specifications

Type	Yanmar Part Number
PV1	D19171-21400

Dimensions



1 – Crankshaft Pulley

Figure 6-180

Unit: mm

PROPELLER SHAFT COUPLING

There are three types of propeller shaft coupling: taper bore, slit and straight bore.

Both the slit and the straight bore types are rough-bored, so it is necessary to provide finishing when matching with the propeller shaft.

Slit type

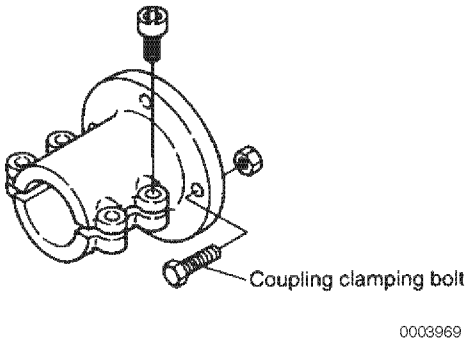


Figure 6-181

Tightening Torque of Coupling Clamping Bolts

Bolt Size	Tightening Torque
M10	4.7 - 5.3 kgf-m 44.1 - 52.0 N·m 34.0 - 38.3 ft-lb
M12	8.5 - 9.5 kgf-m 83.4 - 93.2 N·m 61.5 - 69.0 ft-lb
M14	12.0 - 13.0 kgf-m 118 - 127.5 N·m 87.0 - 94.0 ft-lb

Slit-Type

ϕD indicates rough bores. These should only be used for after fine boring within the range of the maximum re-bore diameter.

For re-boring, insert a 4.0 mm spacer in the slits, clamp with 4 or 6 hexagon socket head cap screws, and re-bore.

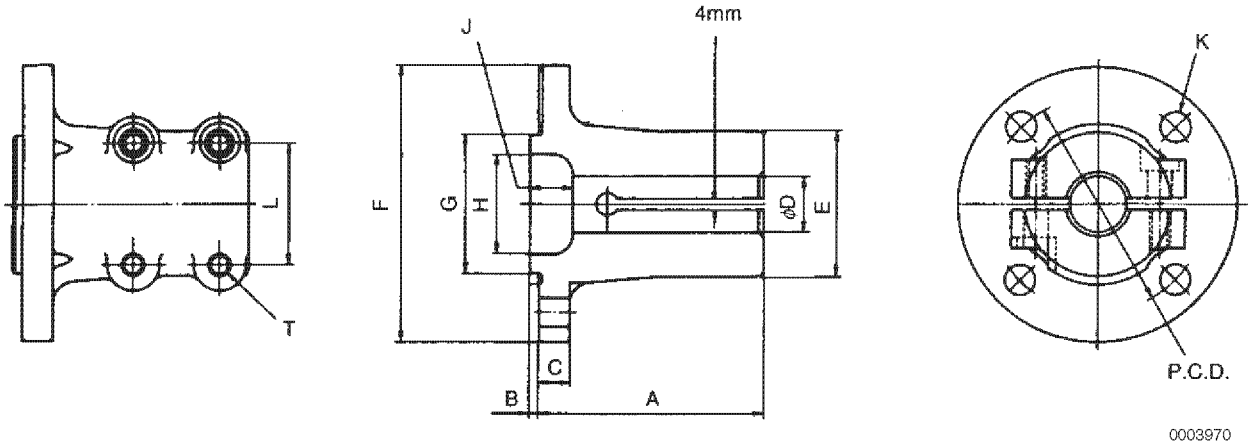


Figure 6-182

Dimensions

Type	Maximum Re-bore Diameter	ϕD (mm)	PCD (mm)	K	T	L (mm)	A (mm)	B (mm)	C (mm)	E (mm)	F (mm)	G (mm)	H (mm)	J (mm)	Yanmar Part Number
CSG1	31.75	20	78	4 x 10.5	4 x M8	40	80	3	11	52	100	50	36	15	D04214-85500
CSJ1	40	25	100	4 x 10.5	6 x M12	59	110	3	13	62	120	65	56	17	D29470-85500

Taper Type (1/10 Taper)

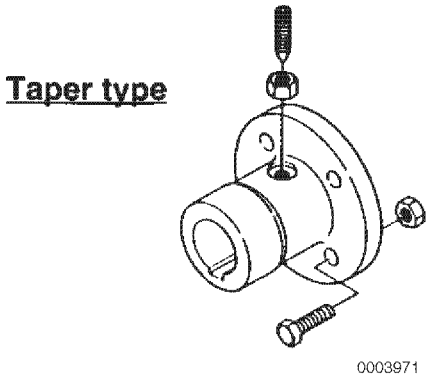


Figure 6-183

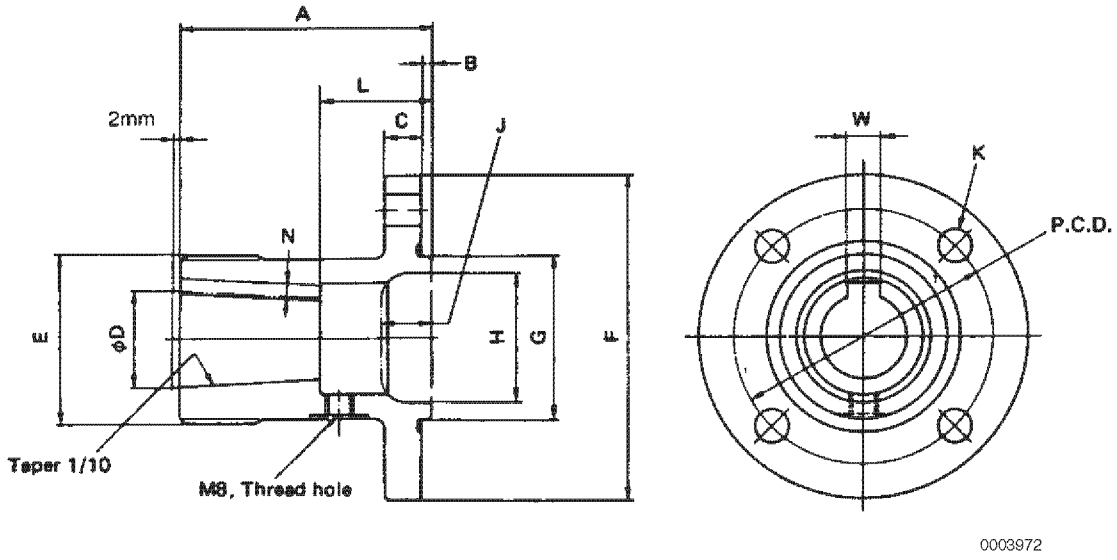


Figure 6-184

Dimensions

Type	ϕD (mm)	PCD (mm)	K (mm)	A (mm)	B (mm)	C (mm)	L (mm)	E (mm)	F (mm)	G (mm)	H (mm)	J (mm)	W (mm)	N (mm)	Yanmar Part Number
CTG1	22	78	4 x 10.5	73	3	11	43	52	100	50	36	27	7	3.5	D05282-85100
CTG2	25	↑	↑	↑	↑	↑	34	↑	↑	↑	40	15	↑	↑	D05582-85100
CTG3	28	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	D05583-85100
CTG4	30	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	10	4	D24771-85100
CTG5	32	↑	↑	76	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	D29171-85100
CTG6	34	↑	↑	80	↑	↑	↑	54	↑	↑	↑	↑	↑	↑	D29670-85100
CTJ1	28	100	↑	88	4	13	35	62	120	65	50	16	↑	↑	D24790-85100
CTJ2	30	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	D24791-85100
CTJ3	32	↑	↑	↑	↑	↑	37	↑	↑	↑	↑	↑	↑	↑	D28696-85100
CTJ4	34	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	D21391-85100
CTJ5	38	↑	↑	↑	↑	↑	—	75	↑	↑	52	33	12	↑	D29473-85100
CTJ6	40	↑	↑	↑	↑	↑	—	↑	↑	↑	↑	↑	↑	↑	D29473-85200
CTJ7	42	↑	↑	94	↑	↑	33	↑	↑	↑	↑	—	↑	↑	D29574-85100

Straight-Type, Rough Bore

ϕD shows rough bores. For use, provide fine boring within the maximum re-boring range.

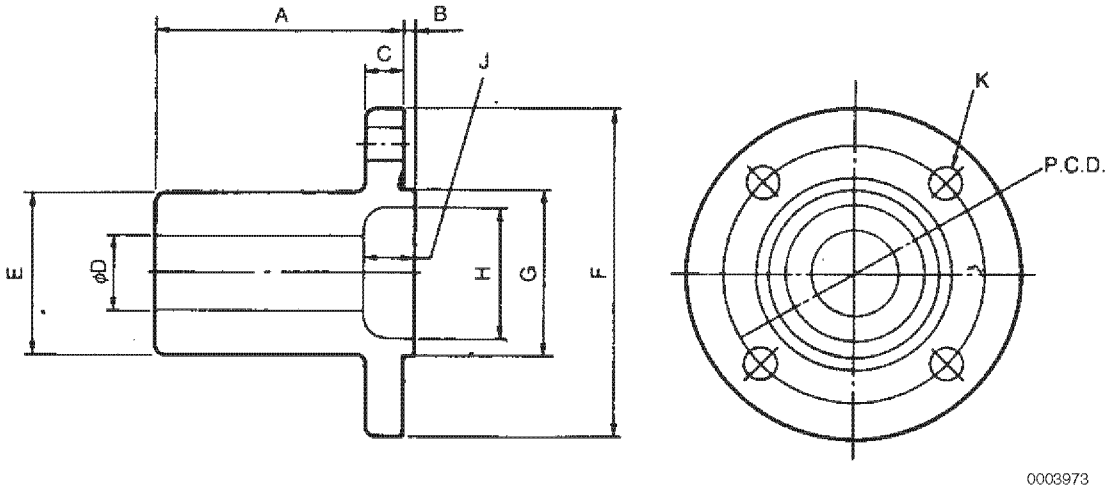


Figure 6-185

Dimensions

Type	Maximum Re-bore Diameter	ϕD (mm)	PCD (mm)	K (mm)	A (mm)	B (mm)	C (mm)	E (mm)	F (mm)	G (mm)	H (mm)	J (mm)	Yanmar Part Number
CRG1	32	16	78	4 x 11	73	3	11	52	100	50	40	27	D04271-85300
CRG2	32	22	78	4 x 11	73	3	11	52	100	50	40	15	D05283-85100
CRJ1	42	20	100	4 x 10.5	88	4	13	62	120	65	50	16	D29470-85100
CRL1	50	30	108	4 x 12.3	95	5	12	75	130	63	57	40	D19171-85100
CRY1	60	28	120.65	6 x 16.3	104	—	14	96	146	—	76.2	5	D19593-85100
CRX1	70	35	146	6 x 15.2	124	4	16	120	175	110	100	42	177066-03750

Note: Type CRX1 for standard accessories.

FLEXIBLE ENGINE MOUNT

Separate Type

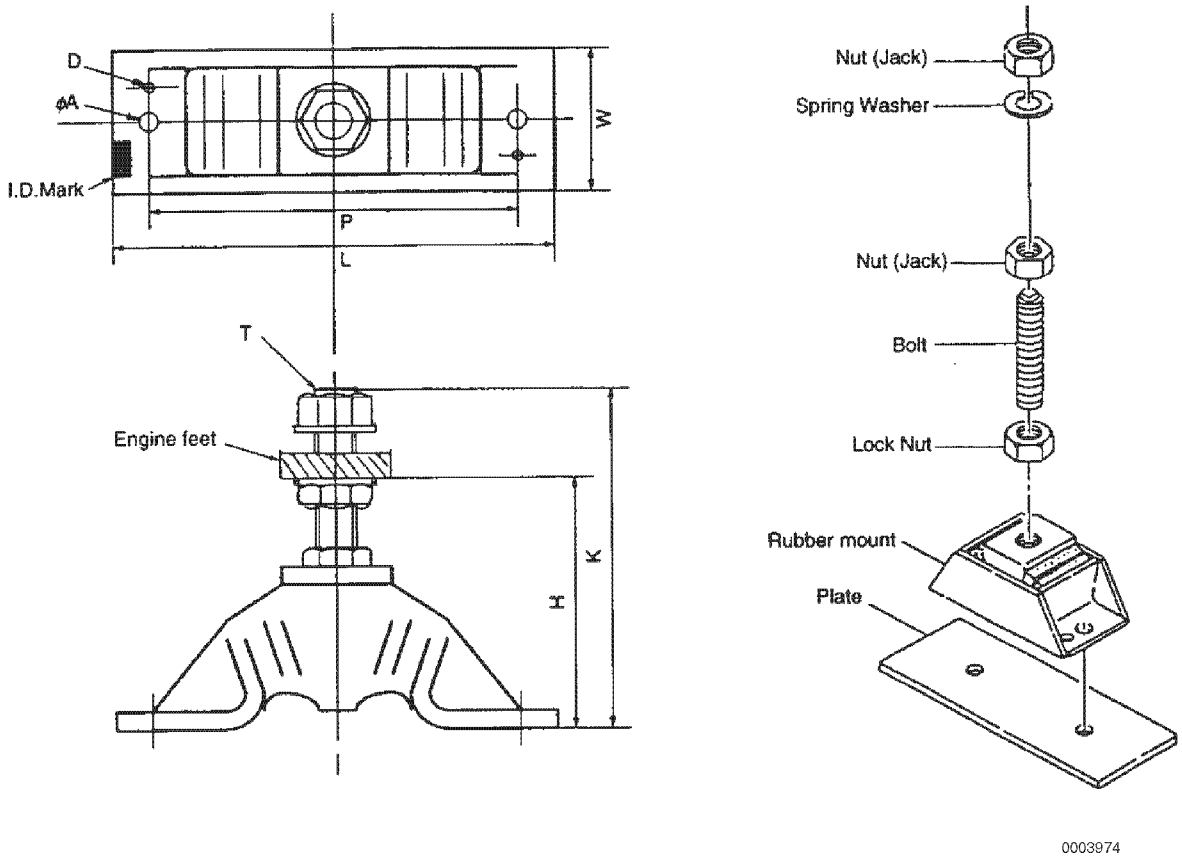


Figure 6-186

Dimensions

Type	ID Mark	H		K (mm)	L (mm)	P (mm)	W (mm)	ϕA (mm)	D Thread Hole	T Thread Diameter
		Minimum (mm)	Maximum (mm)							
Separate	600	100 (80)	120 (100)	189 (166)	210	170	105	2 x 18.5	2 x M12 x 1.75	M27 x 2.0
	900	↑	↑	↑	↑	↑	↑	↑	↑	↑

Note: ( ) value of applicable engine model for 6LY(A)-Series.

Tightening Torque of Clamp Nut

Nut Size	Tightening Torque
M27 x 2.0	27 - 32 kgf-m (265 - 314 N·m) (195 - 232 ft-lb)

Fixed-2 Type

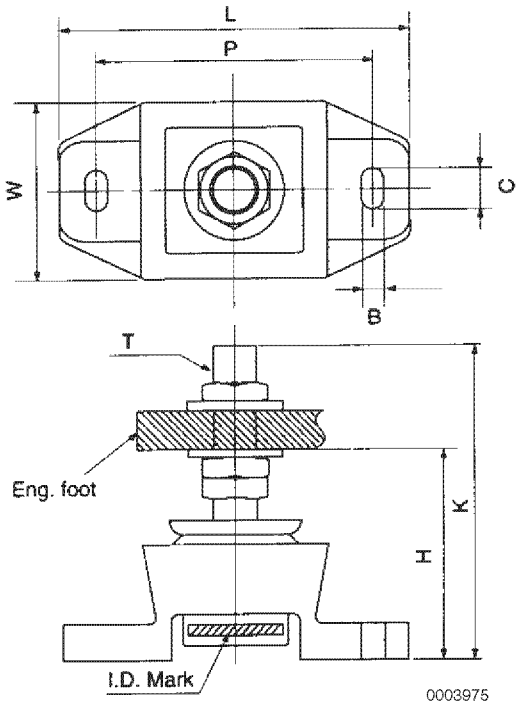


Figure 6-187

Dimensions

Type	ID Mark	H		K (mm)	L (mm)	P (mm)	B (mm)	C (mm)	W (mm)	T Thread Diameter (mm)	ID Color
		Minimum (mm)	Maximum (mm)								
Fixed-2	81860 27391-10	110	120	184	165	127	15	25	96	1 in.	Blue
	81860 27391-11	110	120	184	165	127	15	25	96	1 in.	Red

Tightening Torque of Clamp Nut

Nut Size	Tightening Torque
1 in.	25 - 30 kgf-m (245 - 294 N·m) (181 - 217 ft-lb)

Installed Position

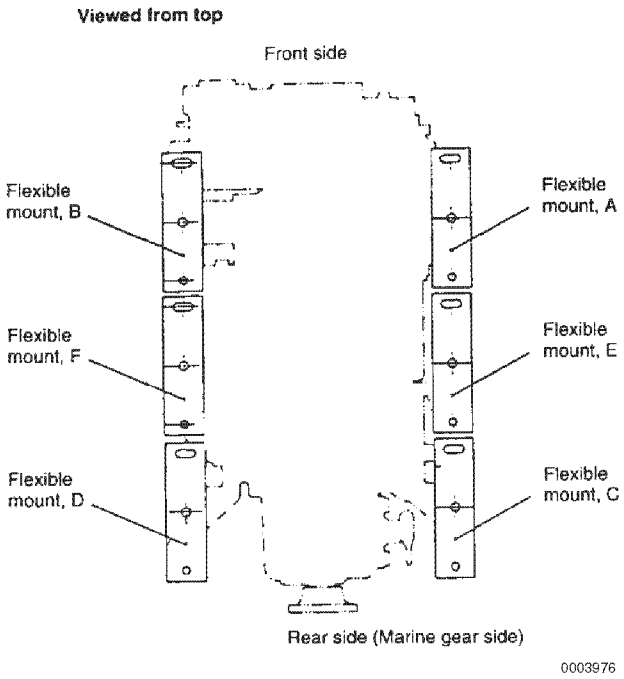


Figure 6-188

Rubber Static Distortion Value

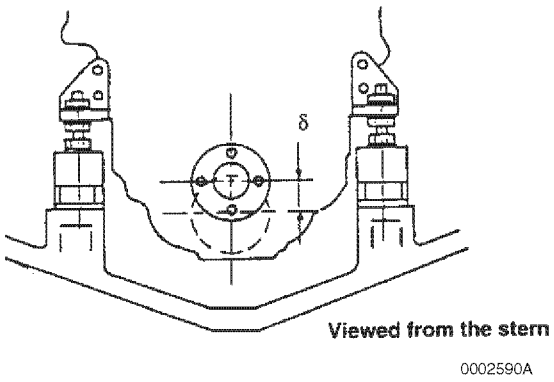


Figure 6-189

Note: Even with the use of flexible engine mounts specified for each engine model, large hull vibrations may still result depending on the hull strength and the engine installation position. In such cases, the use of different flexible mounts may be advisable (flexible engine mounts with higher ID number have a larger spring constant).

ENGINE ROOM

The overall layout of the engine room is planned for easy inspection, servicing and handling of the engine front PTO and auxiliary equipment.

Allow space for the fuel tank, battery and seacock and their related piping, wiring and remote control cables. Thoroughly study all equipment and devices to be installed, consult with the boat builder, and draw up a plan to provide optimum engine room space. The following conditions should be met:

Ventilation of the Engine Room

When the engine room temperature rises after long operation, the air intake volume decreases (as air is heated, its volume expands, and oxygen gets thinner), adversely affecting combustion, raising exhaust gas temperatures, increasing exhaust density and lowering horsepower. Accordingly, it is important to feed fresh air to the engine room through proper ventilation.

1. Calculation of the required ventilation volume (Q):
   Naturally aspirated engines:
   Q = 0.13 x Maximum output (hp) = m^3/min.
   Turbocharged engine:
   Q = 0.15 x Maximum output (hp) = m^3/min.

Engine Room Temperature

1. Heat resistance of electrical devices: At 20 mm (0.79 in.) from the generator or alternator, the temperature should not exceed 60°C (140°F).
2. Temperature of the engine intake air: At the inlet of the intake air cleaner, the temperature should not exceed 45°C (113°F).

Ventilation by Air Duct

The simplest ventilation is made by the intake and exhaust air ducts. An air intake cover is attached at the aperture end of the intake air duct to receive the air while the boat is cruising. The intake air from the duct is released near the engine's air inlet.

Proper arrangements must be made to prevent seawater from entering the inlet of the duct.

1. Calculations of duct area (S) (ventilation using ducts only):

$$\text{Duct Area}(S) = \frac{(Q)}{(V)} = m^2$$

(Q): Required ventilation volume = m^3/min.
(V): Duct area velocity = m/min.

Notes:

- Substitute the boat speed (m/sec) with the duct velocity (V) when installing a duct on the engine room front.
- V = Maximum 10 m/sec when installing a duct on the engine room side.
- 1 knot = 1852 m/hr.
- The piping resistance for a duct pipe or hose is not considered in this calculation. This piping resistance should be included when relevant.

2. Ventilation using ducts only: Install both inlet and outlet ducts. However, if the engine room is not completely closed, it is sufficient only to install an inlet duct and to use the engine room door or window as the air outlet.

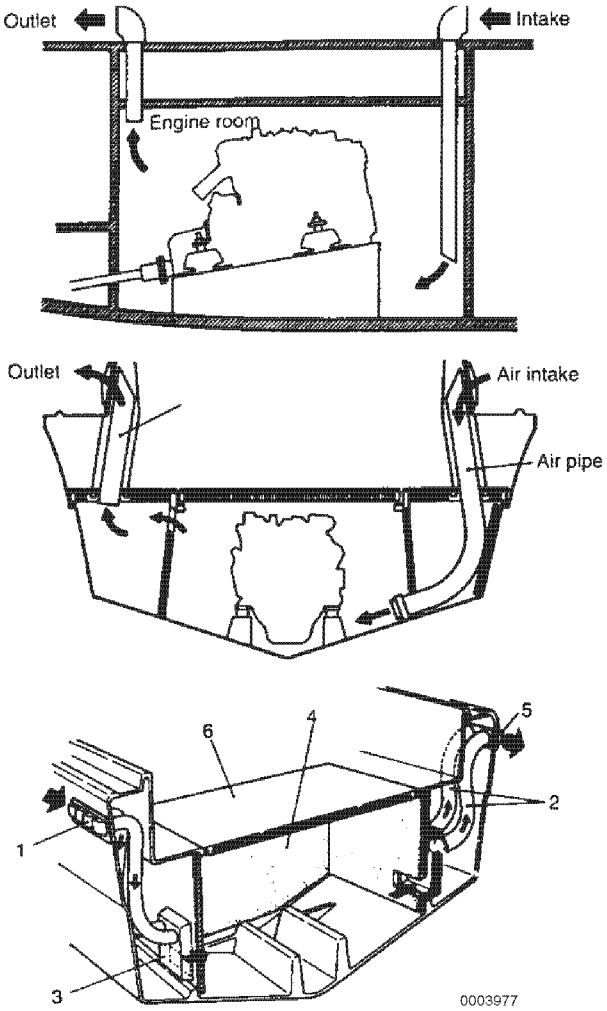
   Example: Ventilation for a boat equipped with a naturally aspirated engine (maximum 100 hp), boat speed 10 knots:
   From ventilation volume: (Q)
   Q = 0.13 x 100 = 13 m^3/min. or greater

   From intake duct air: (S)

$$S = \frac{13}{308.6^*} = 0.0421\ m^2 = 421\ cm^2 \text{ or greater}$$

$$308.6^* = 10\ \text{Knots} \times \frac{1852\ m}{60\ \text{min.}}$$

Example of layout of air intake and ventilation for engines:



1 – Air Intake, Water Separator (Free Area)
2 – Double Air Pipes
3 – Sound Baffle (Insulation)
4 – Sound Insulated Engine Room
5 – Outlet for Ventilating Air (Free area same as 1)
6 – Sound Insulated Hatches

Figure 6-190

Attach the exhaust duct at the lowest possible position opposite the intake duct, and place the duct end in the open air outboard.

The duct pipe should be as short as possible.

Avoid bending as much as possible.

If the temperature of the engine room cannot be lowered, use a larger diameter duct pipe, or increase the number of pipes.

Ventilation Using Electrical Draft Fans

There are two ventilation methods of this type: the forced draft fan (attached to the intake duct side) system, and the induced draft fan (attached to the exhaust duct side) system.

In both cases, use a fan within the rated capacity of the electrical equipment.

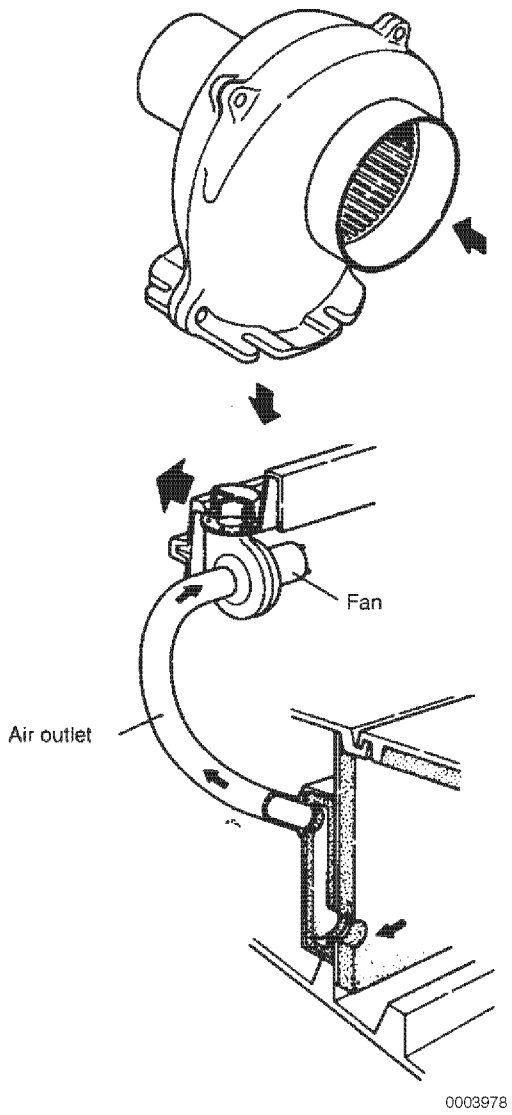


Figure 6-191

1. Capacity of electrical type draft fan:
   Draft fan capacity = Identical to the required ventilation volume: (Q) m^3/min.
   (a) Ventilation by draft fans only
   Two draft fans with the same capacity (Q) are used for the inlet and outlet.
   (b) Combination of draft fan and duct
   The draft fan should be used for the outlet.

Soundproofing the Engine Room

Soundproof Structure

To prevent noise from the engine room, it is necessary to separate the engine room from other sections of the boat and to cover all noise sources, such as the engine and marine gear or sail drive.

Construct the engine room out of wood or MDF, and provide a hinged door or lid in the roof. When the engine room wall vibrates, the secondary noise caused by this vibration is transmitted outside the engine room, so make the engine room wall strong as possible and extend the wall to the bottom of the hull. Attach it firmly to the bottom of the boat. Also install soundproof material inside the engine room.

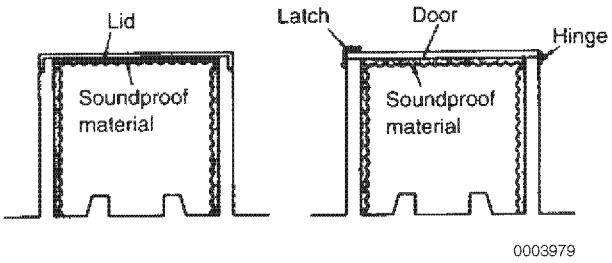
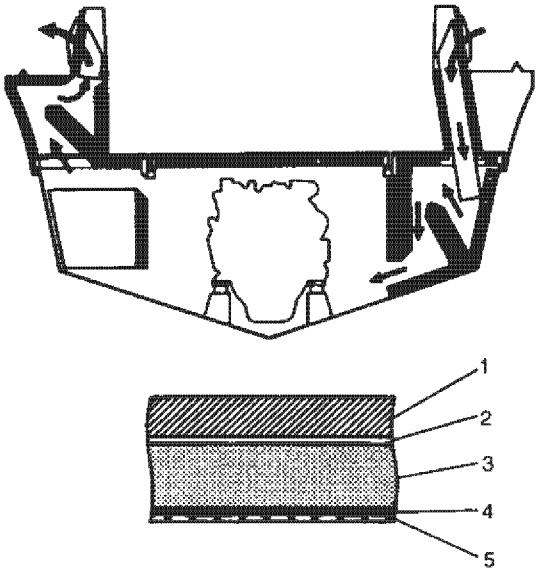


Figure 6-192

Example of Soundproofing:

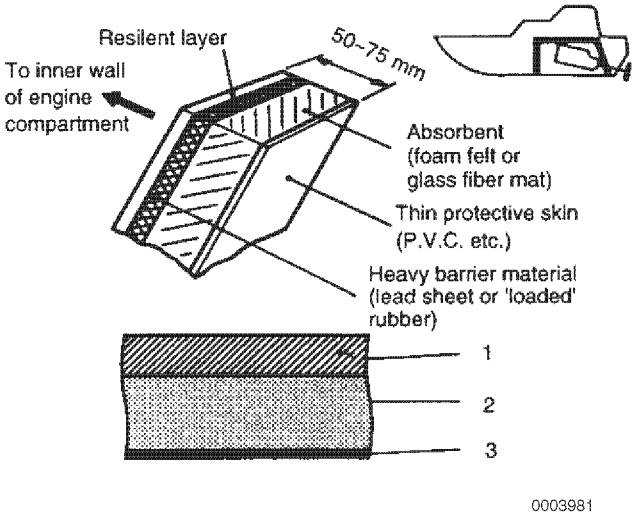
Note: The sizes and materials shown here are for reference only. They vary depending on the hull size and the size of the engine compartment.



1 – Engine Casing
2 – Lead Plating, Thickness = 1 mm
3 – Mineral-Wool, Thickness = 50 mm
4 – Plastic Sheeting
5 – Perforated Aluminum Sheet, Thickness = 1 mm, 20% Perforated

Figure 6-193

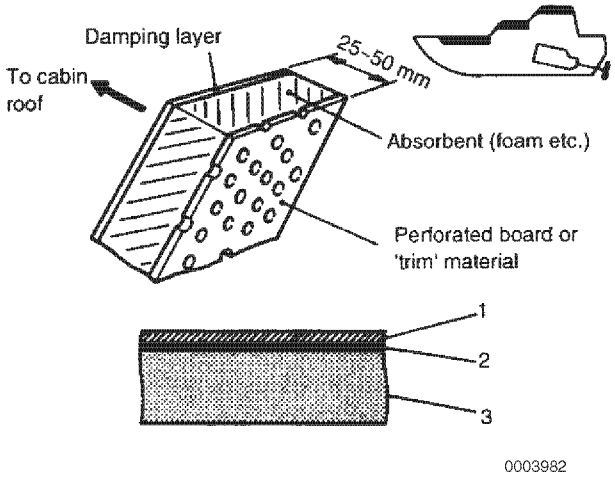
Insulation material (alternative): Plywood engine casing - 15 mm (0.59 in.), sheet metal casing - 2 mm (0.08 in.).



1 – Engine Casing
2 – Flame-Proof Absorption Sheeting (such as manufactured by Porolon, Revertex Acoustics or Baryfol)
3 – Flame-Proof Reflection Sound-Insulation Sheeting (Iron-PVC, 2.5 mm thick). The face exposed to the engine should be about 15% covered with absorption sheeting

Figure 6-194

Insulation material for engine casing: 2 mm (0.08 in.) thick sheet metal or 15 mm (0.59 in.) thick plywood.



1 – Engine Casing
2 – Iron-PVC 2.5 mm (0.0984 in.)
3 – Absorption Sheeting
When fiberglass engine casings are to be insulated, use the same material as specified in the above example, but in reverse order so that the hard layer is placed next to the fiberglass casing

Figure 6-195

Insulation material for fiberglass engine casing.

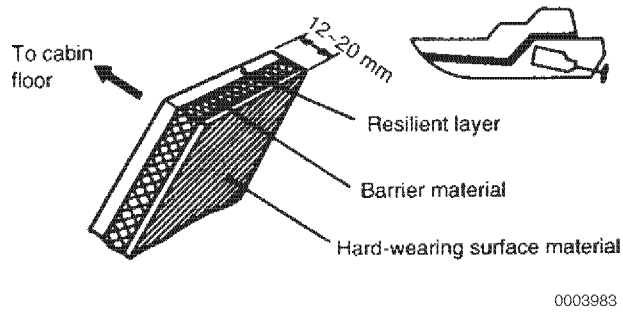


Figure 6-196

Air Venting the Cooling Water Tank (V-Drive Version)

IMPORTANT

If a V-drive marine gear is used, this air-venting device must be installed onto engine.

An air vent releases air from the air sump of cooling water tank (heat exchanger) to prevent engine overheating. Be sure to install this vent when using the V-drive marine gear set engine. It is possible to install this equipment after installing the engine.

When engines are installed with the parallel and angle drive marine gears, it is common to direct the engine's flywheel to stern and the crankshaft pulley to bow. The engine installed in this case causes the crankshaft pulley to nose up to the waterline. This means that the bow will nose up and the engine inclination will further increase when the boat cruises at a high speed.

Yanmar, assuming the cruising condition like this, determines the capacities of the engine's lube oil tank and heat exchanger. The allowable engine installation angle, too, is specified to prevent any trouble due to air being sucked into the lube oil or cooling water.

However, when installing engines with a V-drive marine gear, the crankshaft pulley faces toward the stern and the flywheel to bow. The engines are installed in the reverse direction to the installation of the parallel and angle drive set engines. In this case, the crankshaft pulley side of the engine noses down and the bow will further rise when the boat cruises at a high speed, causing the engine to further nose down. In this condition, air is trapped in the cooling tank. The air in the air sump expands as the temperature of cooling water rises, causing the cooling water to blow out to the coolant recovery tank from the pressure cap. This causes the cooling water in the coolant recovery tank to decrease and the engine to overheat. The air venting equipment releases air of the air sump in the cooling water tank.

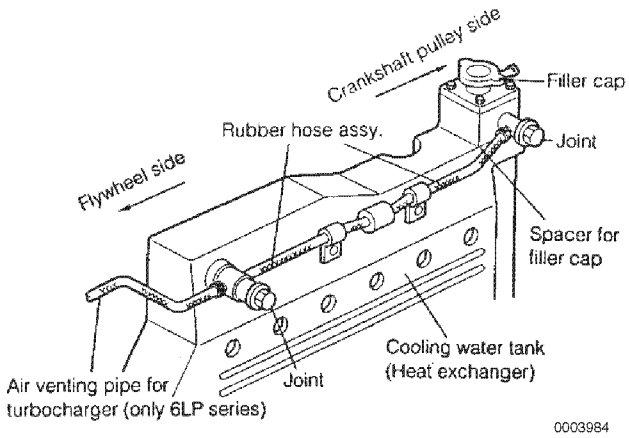


Figure 6-197

Arrangement of Marine Gears

- Parallel Drive
- Angle Drive
- V-Drive

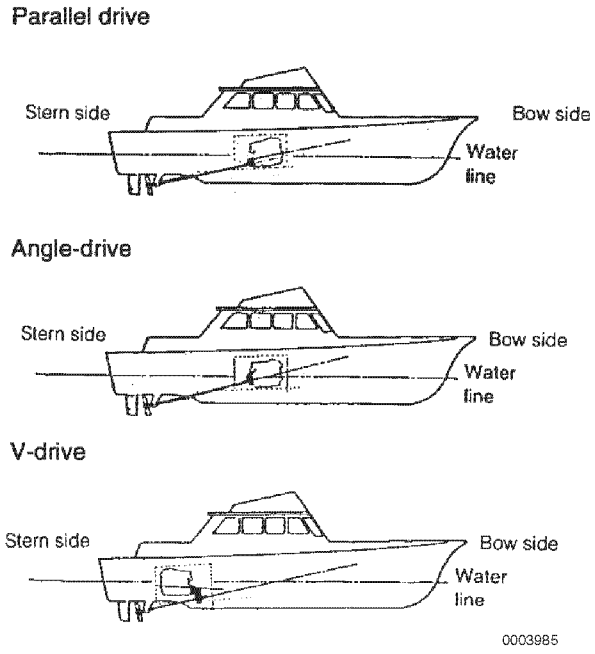


Figure 6-198

Specifications

Type	Accessories Name	Allowable Engine Installation Angle for Nose Down, Maximum			Yanmar Part Number
		Static	Cruising Condition		
LHA	Air Vent Device for Heat Exchanger (V-drive Version)	-2°(0°)	Constant: -7°(-5°)	Peak: -12°(-10°)	D19175-13150
6LP		-2°(0°)	Constant: -7°(-5°)	Peak: -12°(-10°)	D19773-13150
LYA		-2°(0°)	Constant: -7°(-5°)	Peak: -12°(-10°)	D19573-13150

Notes:

1. ( ) the value of the standard specification engine.
2. Minus angle means the nose down of the engine.

BILGE PUMP

Construction and Functions

The bilge pump consists of the motor, pump and auto-stop mechanism. The auto-stop is a unique mechanism. When all bilge is drained, a built-in diaphragm senses that there is no water pressure in the water passage and stops the motor quickly. This prevents premature bilge pump wear.

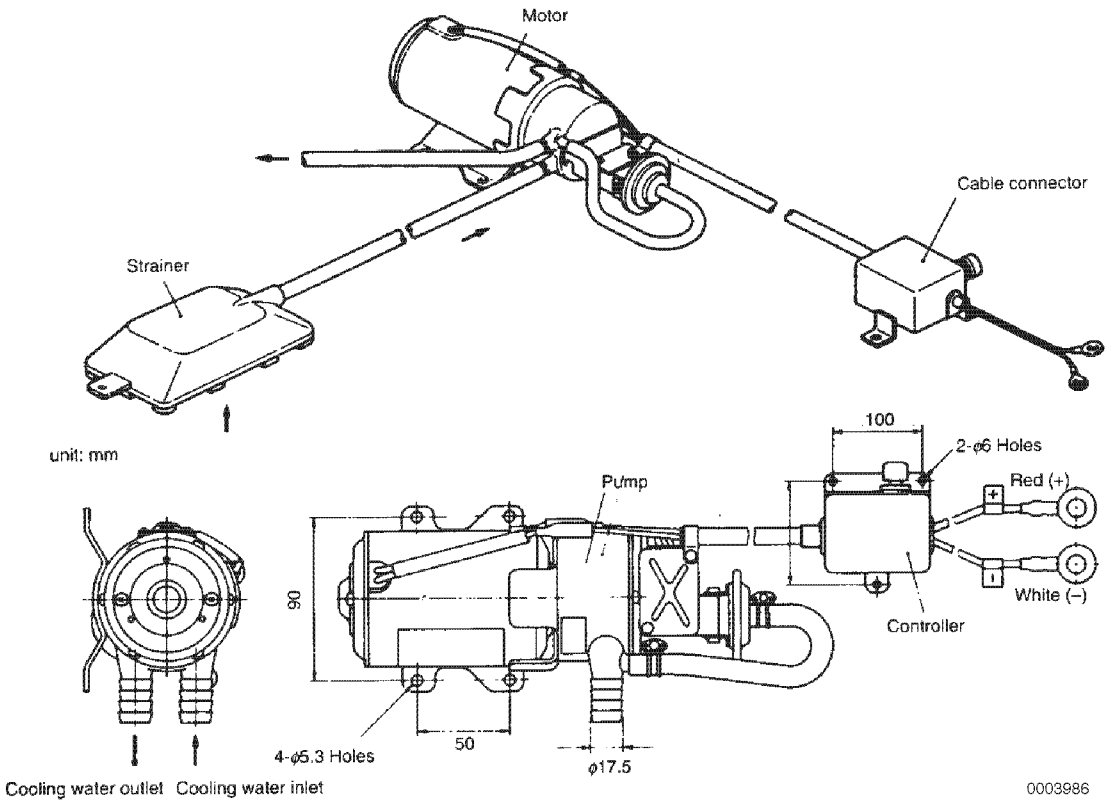


Figure 6-199

Unit: mm

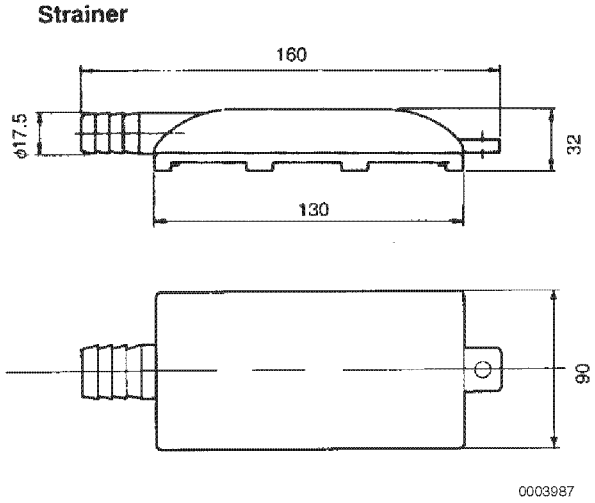


Figure 6-200

Specifications

Type		BP1
Yanmar Part Number		D27675-461001
Motor		
	Model	WP-1220
	Rated Operation Time	10 minutes
	Rated Voltage	12V
	Rated Output	100W
Pump Capacity		
	Self-Suction Head (Maximum)	1.0 m (39.4 in.)
	Self-Suction Time	2 seconds
	Loaded Current	10A
	Flow Volume	20 L/min. (21.1 qt/min.)

Installation of Bilge Pump

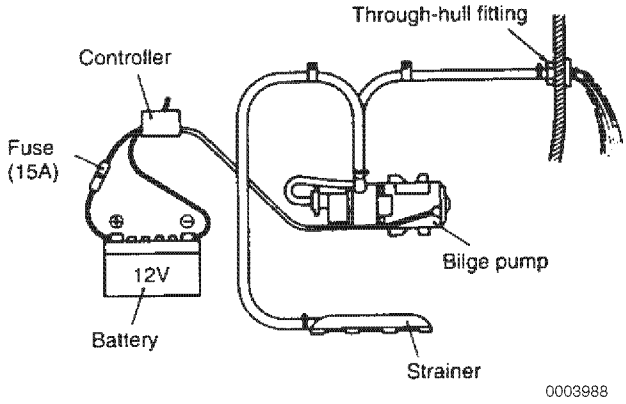


Figure 6-201

Angle of Installation

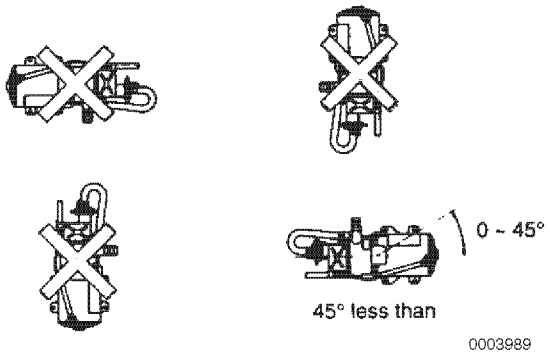


Figure 6-202

Height of Installation

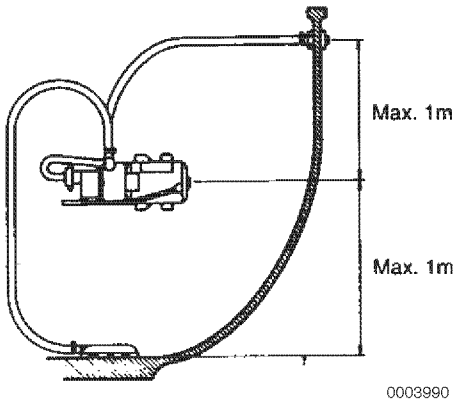


Figure 6-203

Clamping Position

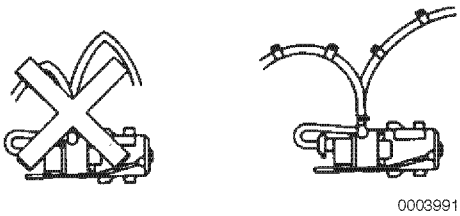


Figure 6-204

Through-Hull Fitting

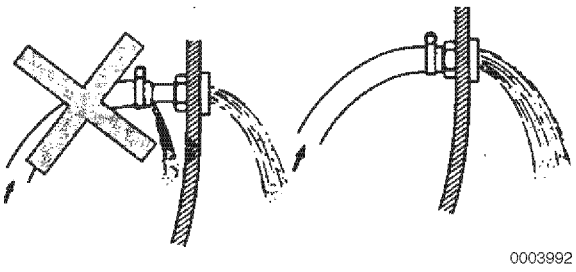


Figure 6-205

MARINE GEAR

The marine gear is installed to convert the fixed direction of the crankshaft into AHEAD, ASTERN and STOPPED operation. The gear does this by means of reversing and reduction mechanisms, with careful reference to the propeller efficiency.

In general, lower revolutions and a large propeller diameter produce higher propeller efficiency and higher boat speeds. The decisive factor in boat speed, however is the selection of the appropriate reduction ratio and propeller match to the shape and weight of the hull and the engine output.

In general, a large reduction ratio is used for boats with a big displacement, such as sailboats, in order to reduce propeller revolutions. These boats usually use a large propeller. Powerboats, which have a light hull and fast boat speeds, use a small reduction ratio to raise propeller speed and a specially shaped propeller with a small diameter but high efficiency.

Type of Marine Gear

Clutch Shift Mechanism

The basic types are the mechanical and the hydraulic mechanisms for ahead, astern and neutral shifts. These are operated by the remote control handle.

1. **Mechanical Type**: The mechanical gear is usually used with pleasure craft engines under 100 hp. The mechanical type is usually in sailboats because the propeller shaft has to be locked when cruising under sail in order to reduce propeller resistance. More force is needed though, to shift gears when using the mechanical type.
2. **Hydraulic Type**: The hydraulic type is usually used for boats with high output engines, especially powerboats. The hydraulic type makes shifting easier and is often used for dual station control systems.

Propeller Drive Mechanism

1. **Parallel Drive**: The output shaft of marine gear is parallel to the crankshaft. The engine is installed at a slant.
2. **Angle Drive**: Also called the down-angle drive system. The output shaft of the marine gear is inclined at 7 - 10° to the crankshaft. the gentle inclination of the engine / marine gear package reduces the engine room space requirements.
3. **V-Drive**: The output shaft of the marine gear makes a V-shape with the input shaft. The propeller shaft is angled backward compared with propeller angle drive, and the engine is installed the opposite way around. The advantage of this type is that more of cabin space is available.

   The disadvantage is the difficulty in selecting flexible engine mounts and the comparatively large loss in horsepower.

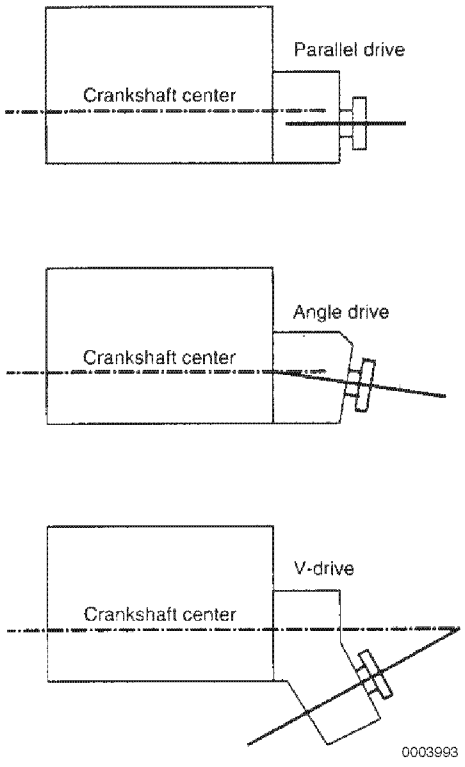


Figure 6-206

Selection of the Marine Gear Capacity

When coupling a locally purchased marine gear to the engine, give the following data to your marine gear supplier:

1. Engine
   - Maximum rating output at flywheel: hp or kW/rpm
   - Maximum engine torque: kgf-cm at rpm
   - Idle speed: rpm
   - Torsional vibration data
2. Marine Gear
   - Maximum allowable input torque: kgf-cm
   - Maximum allowable transmission horsepower: hp or kW/rpm
   - Maximum allowable input speed: rpm

Engine Foot Kit for Marine Gear

In the case of engines supplied by Yanmar without a marine gear, two pieces of engine foot must be installed at the front side (anti-flywheel side). When you install the marine gear recommended by Yanmar to an engine without a marine gear, the engine foot, engine oil cooler hose, etc. (to be installed at the marine gear side) are available as an option.

IMPORTANT

Mounts are installed at both sides of the flywheel housing of the engine. These mounts are the dummy feet for transport and packing and cannot be used for engine installation. Discard before installing the foot kit. Also, note that the installation positions of these dummy feet are not the correct positions for actual marine gear installation. If you install the marine gear and engine with leaving the dummy feet, excessive engine vibrations and other troubles will be caused due to insufficient strength of the dummy feet. Any trouble due to the use of the dummy engine feet or engine installation at the dummy engine foot installation position will not be covered by Yanmar's Warranty.

Kit Type

Type	Components	Applicable Marine Gear	Yanmar Part Number
LH	• Engine foot (2 pieces) and bolts, M12 x 35 (8 pieces) • Rubber hoses (2 pieces) and clamps (6 pieces) • Hose joints (2 pieces) • Clamp bolts, M10 x 25 (18 pieces)	ZF, HSW630A1 HSW630H1	D19175-08150 D19175-49120 D19181-49530 D19773-85600 D19175-81100
LH-1	• Engine foot (2 pieces) and bolts, M12 x 35 (8 pieces) • Rubber hoses (2 pieces) and joint and clamps (2 pieces) • Clamp bolts, M10 x 25 (18 pieces)	ZF, HSW450A2 HSW450H2	D19173-08140
LP	• Engine foot (2 pieces) and bolts, M10 x 30 (6 pieces) • Bracket for lube oil cooler	ZF, HSW630A1 HSW630H1	D19773-85600
LY	• Engine foot (2 pieces) and bolts, 5/8 x 35 (8 pieces) • Bracket and bolts, M10 x 14 (5 pieces) for lube oil cooler • Hose joints (2 pieces) and clamps (2 pieces)	TWIN DISC MG5061A	D19575-85600

LH-Type

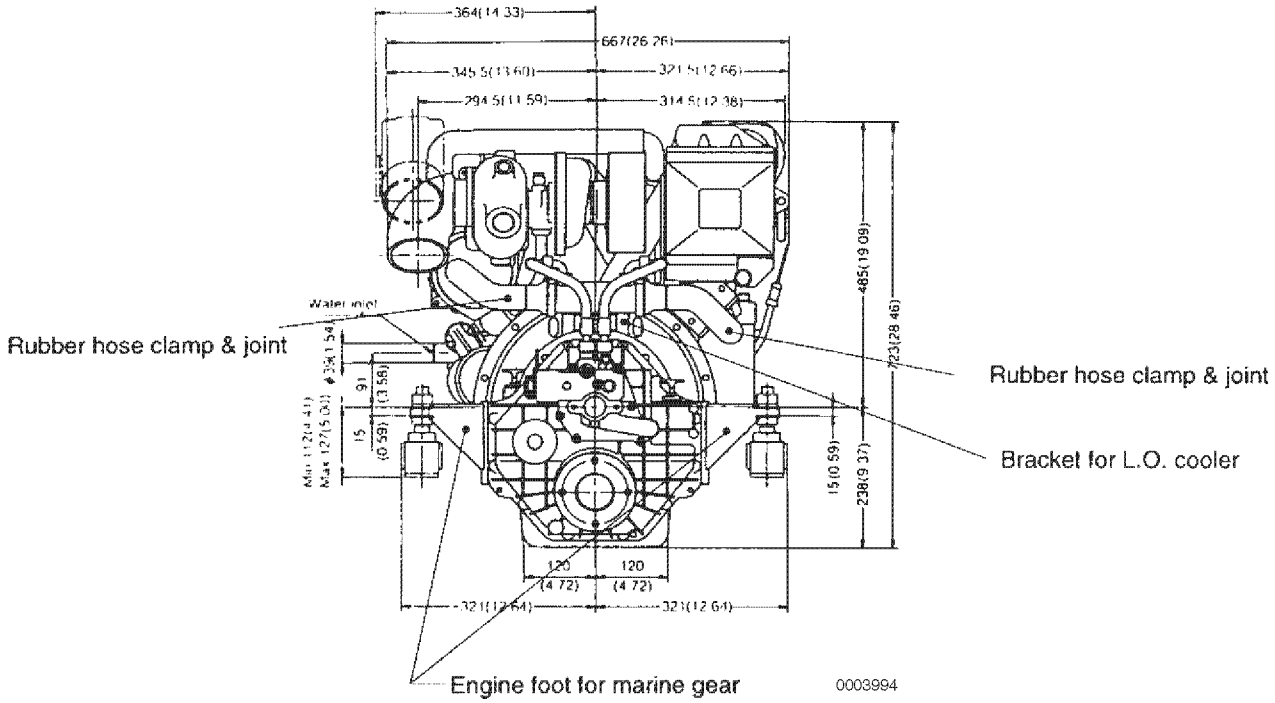


Figure 6-207

Unit: mm (in.)

LP-Type

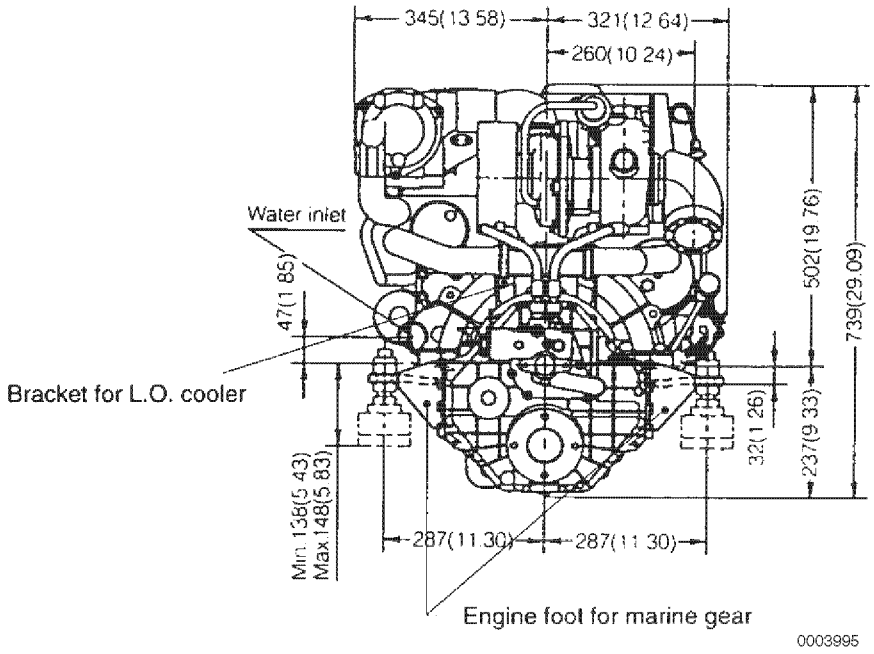


Figure 6-208

Unit: mm (in.)

LY-Type

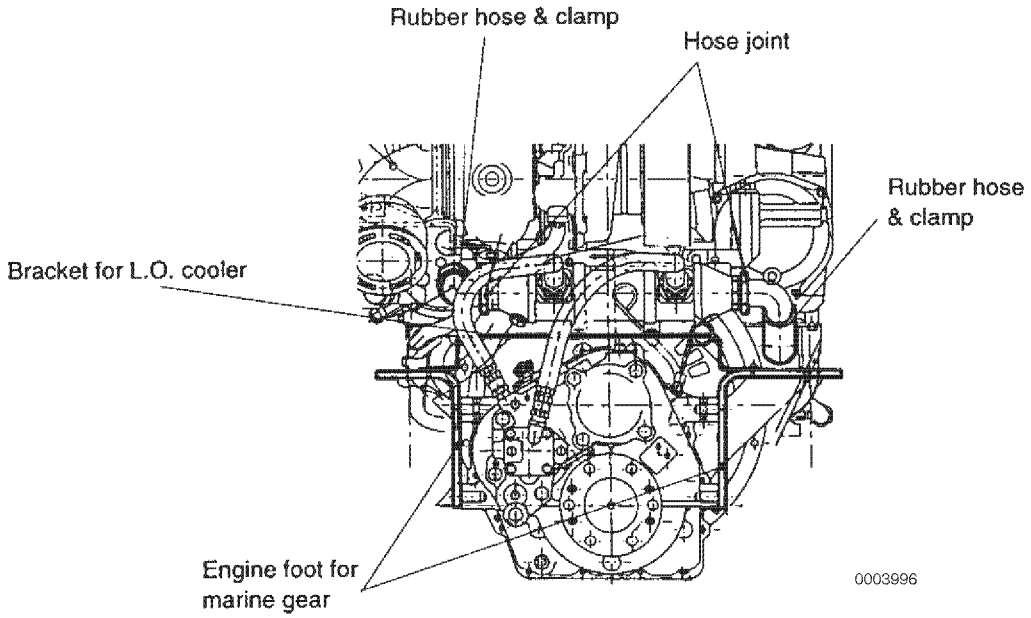


Figure 6-209

Section 7

SAIL DRIVE

Page

Sail Drive Models 7-3
Sail Drive Components..... 7-4
Sail Drive Dimensions 7-5
SD20, SD31, SD40 and SD50 Installation 7-8
Installing Remote Control System 7-16

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SAIL DRIVE MODELS

The models that include sail drive are listed below:

- SD20
- SD31
- SD40 and SD40-4T
- SD50 and SD50-4T

Applicable engine models:

- 1GM10C
- 2GM20C
- 3GM30C
- 3JH2CE
- 3JH2-TCE
- 3JH3CE
- 4JH2CE
- 4JH3CE
- 4JH3CE1
- 3JH4E
- 4JH4E
- 4JH4-TE
- 3YM30
- 3YM20
- 2YM15

Sail Drive Components

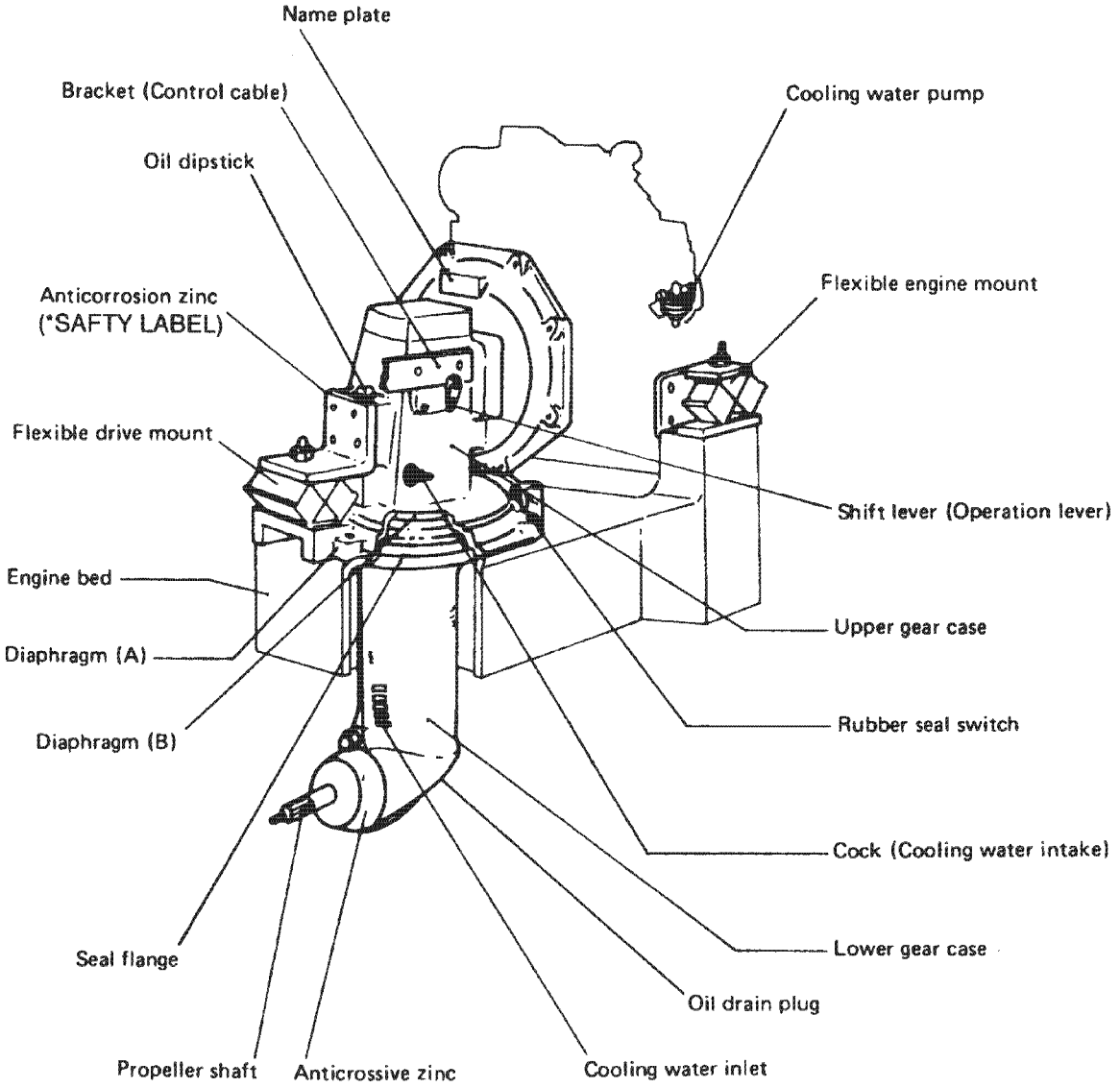

Figure 7-1

Sail Drive Dimensions

Propeller Shaft and Nut

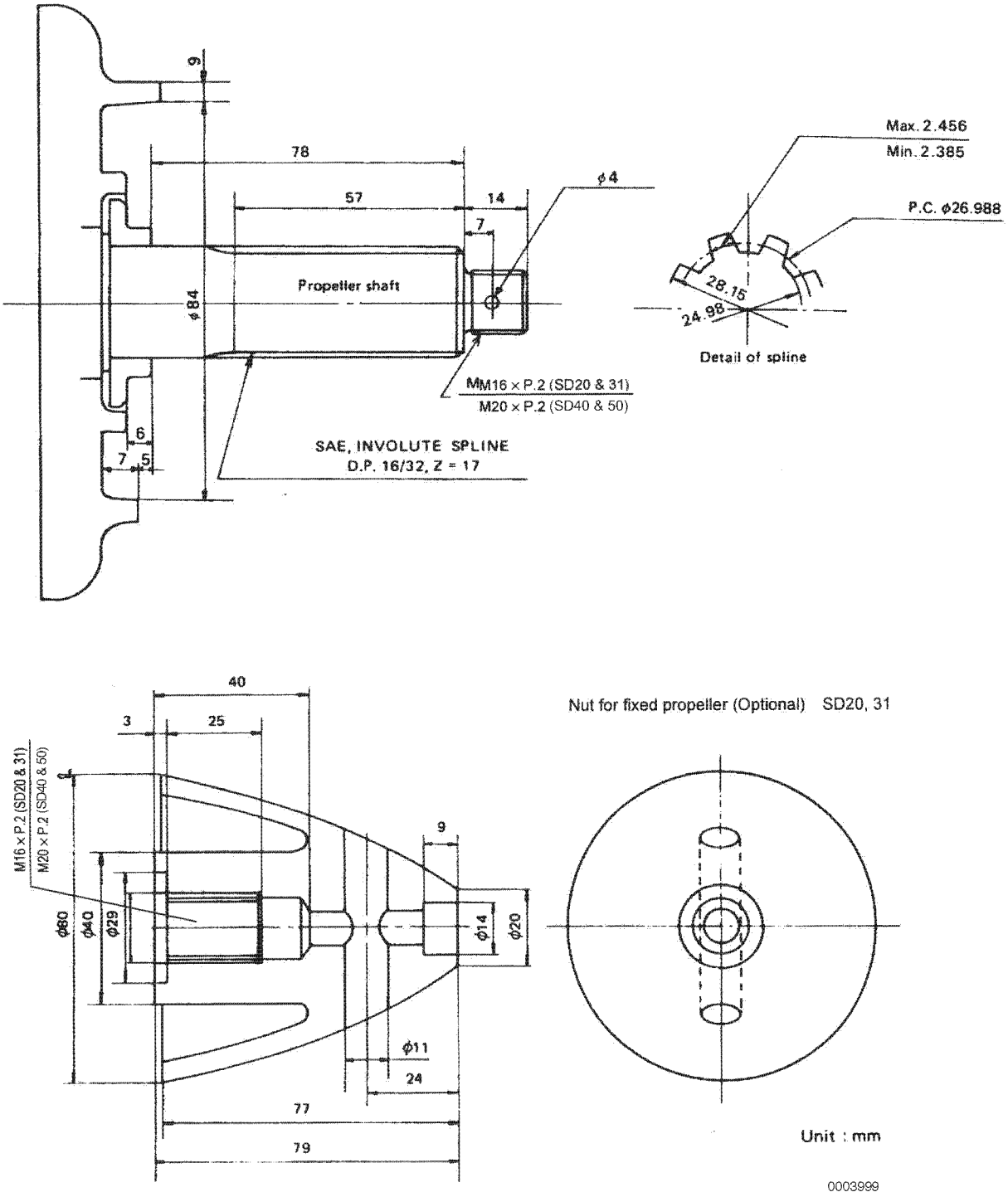

Figure 7-2

Fitting for Engine Bed

Make an engine bed that fits the bottom of the boat. The (A) dimension in **Figure 7-3** should be no greater than 75 mm, as a larger dimension will result in the propeller being raised and it may foul the hull. To determine the proper engine bed size, use the jig as illustrated.

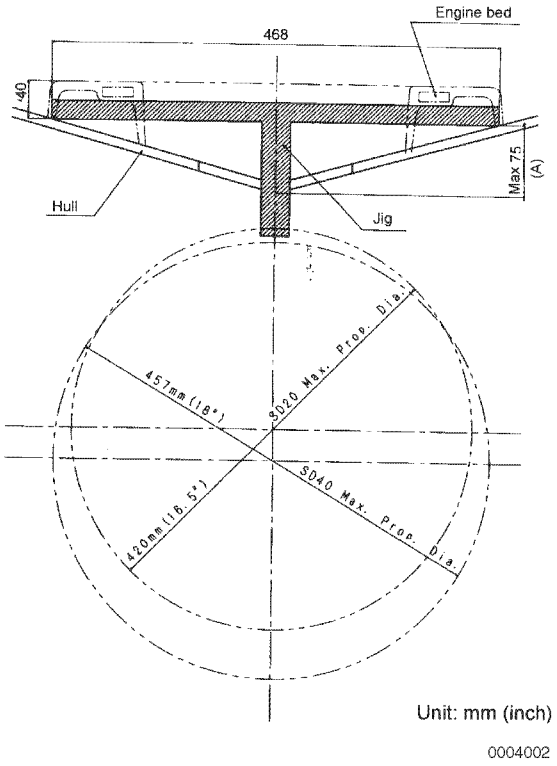

Figure 7-3

SD20 and 31 Long-Reach Unit

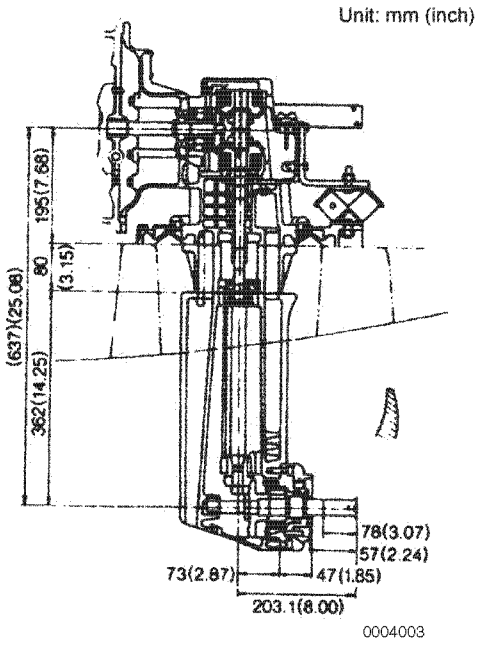

Figure 7-4

Long-Reach Unit (Extension 80 ft Kit) Optional Parts

For installation in hulls with a high engine bed, the SD20 and 31 includes extended shaft models with an 80 mm longer reach than the standard units.

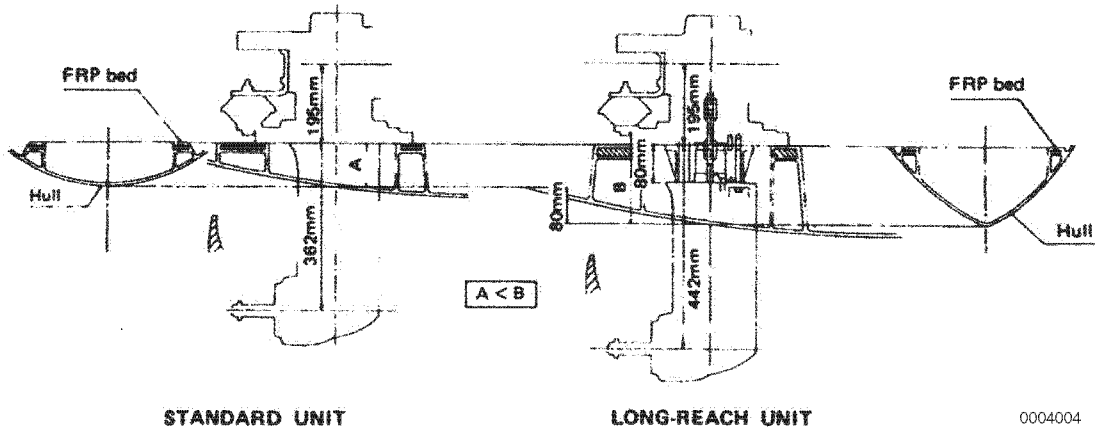

Figure 7-5

SD40 and SD50

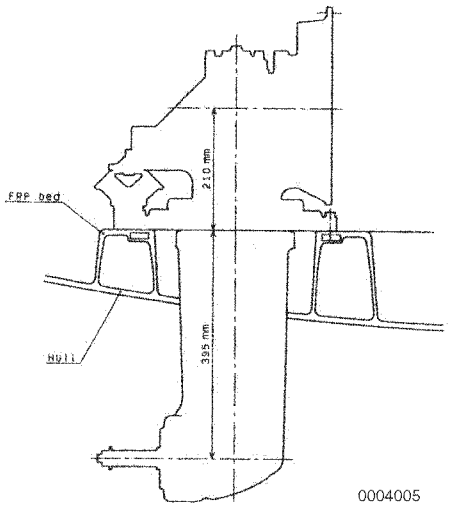

Figure 7-6

SD20, SD31, SD40 and SD50 Installation

1. Put engine bed in hull bottom.

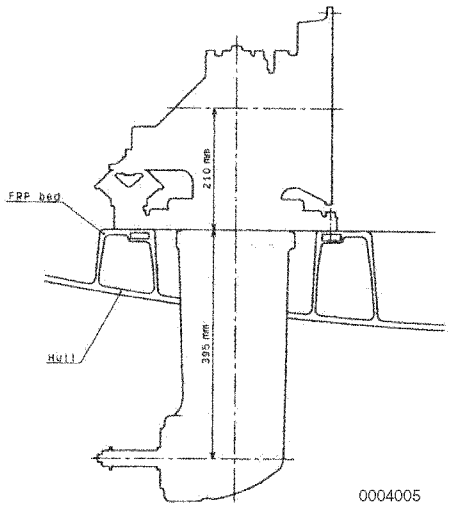

Figure 7-7

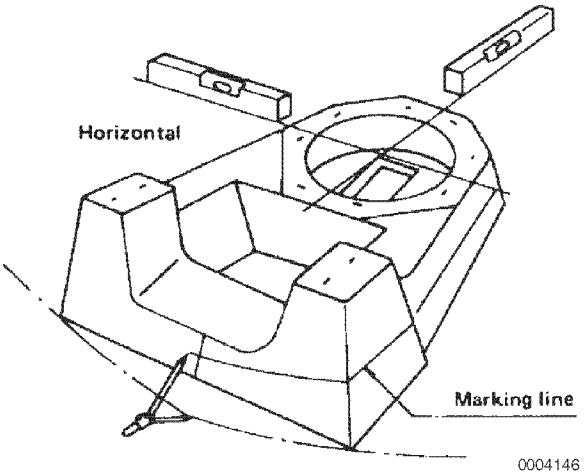

Figure 7-8

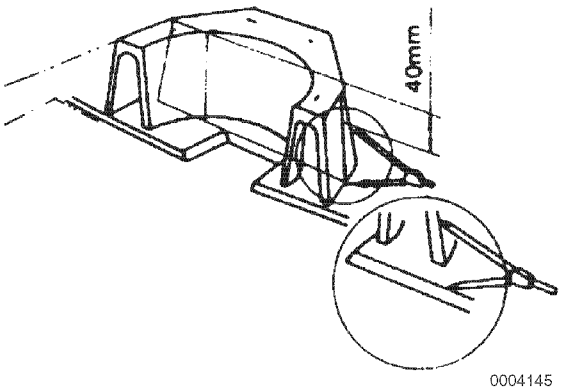

Figure 7-9

2. Level the engine bed fore and aft and port-to-starboard, and ensure it is centered along the keel.
3. Mark the bottom of the hull around all outer and inner surfaces of the engine bed.
4. Use a compass to scribe a cutting line around the entire engine bed. Start at a point 40 mm (1.57 in.) down from the drive mounting surface.

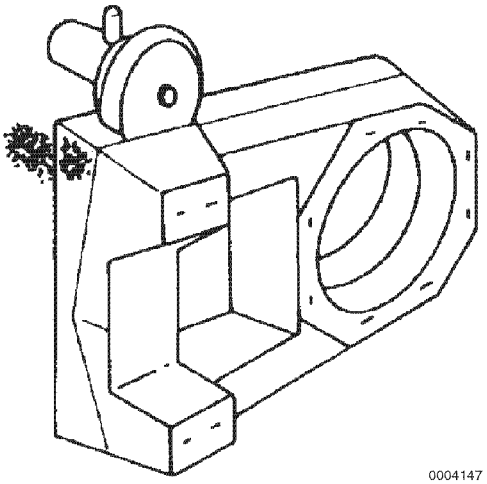

Figure 7-10

5. Remove the engine bed and cut along the line **(Figure 7-10)**.

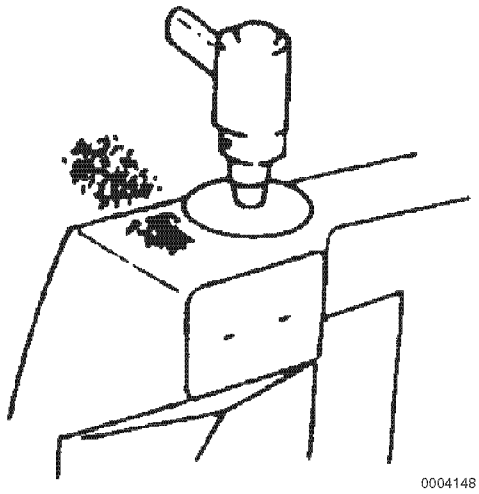

Figure 7-11

6. Grind the areas where fiberglass will be used to fasten bed to hull bottom to ensure a good bond. **(Figure 7-11)**.

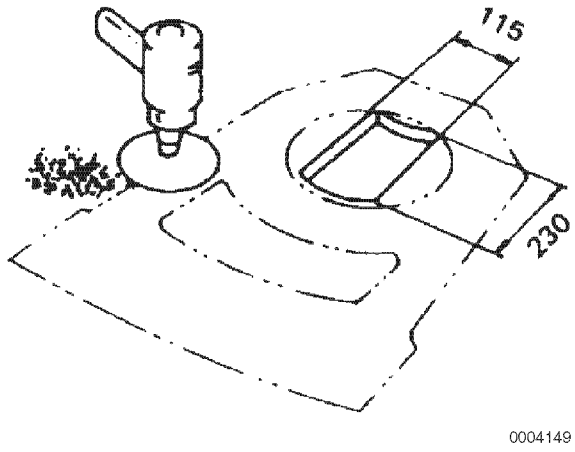

Figure 7-12

7. Cut a 230 mm x 115 mm (9.06 x 4.53 in.) hole through the hull bottom in **Figure 7-12**.

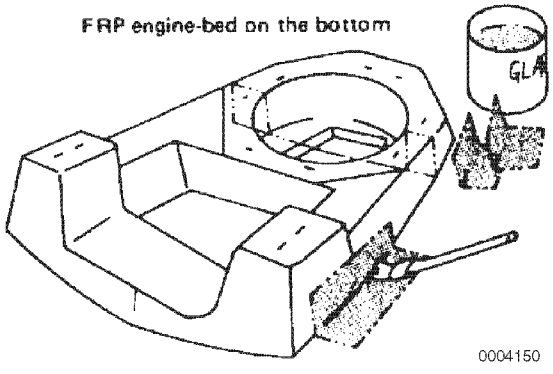

Figure 7-13

8. Secure the engine bed to the hull bottom using fiberglass fabric and resin **(Figure 7-13)**.

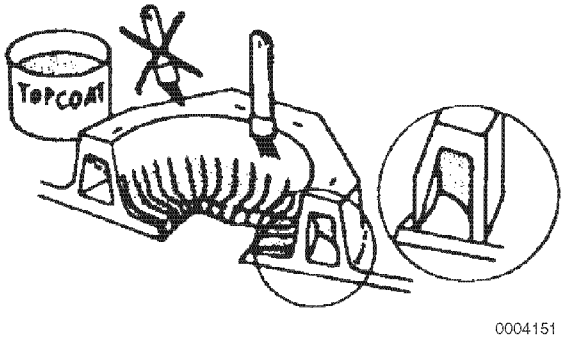

Figure 7-14

9. Apply a layer of glass fabric and resin to completely seal the cavity around the sail drive installation hole **(Figure 7-14)**.

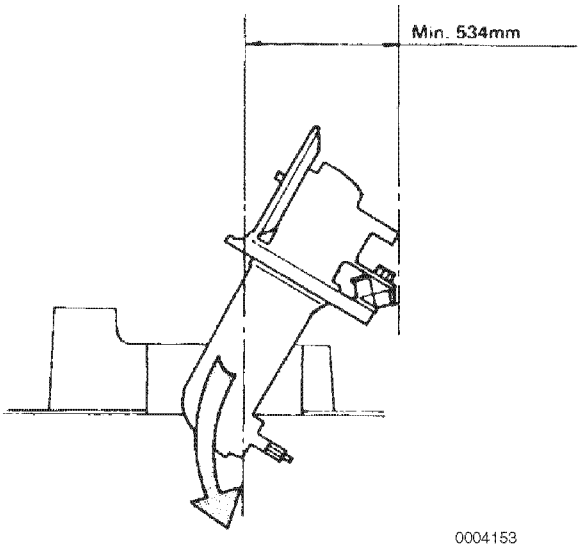

Figure 7-15

IMPORTANT

Cover the rough edges of the hole with a soft material to protect the drive unit surface from damage during installation.

10. When the resin has cured, carefully pass the sail drive through the hull bottom **(Figure 7-15)**. Loosely install the attaching hardware but do not tighten at this time.

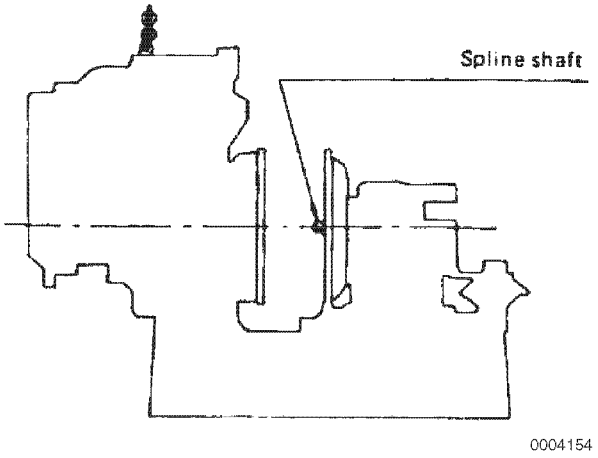

Figure 7-16

11. Lightly grease the splines and install the engine being careful to engage the splined shaft as the assemblies are moved together **(Figure 7-16)**.

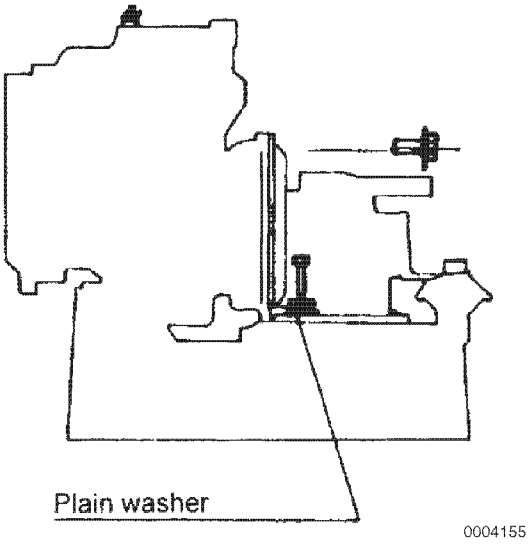

Figure 7-17

12. Install the attaching hardware and tighten to specification **(Figure 7-17)**.

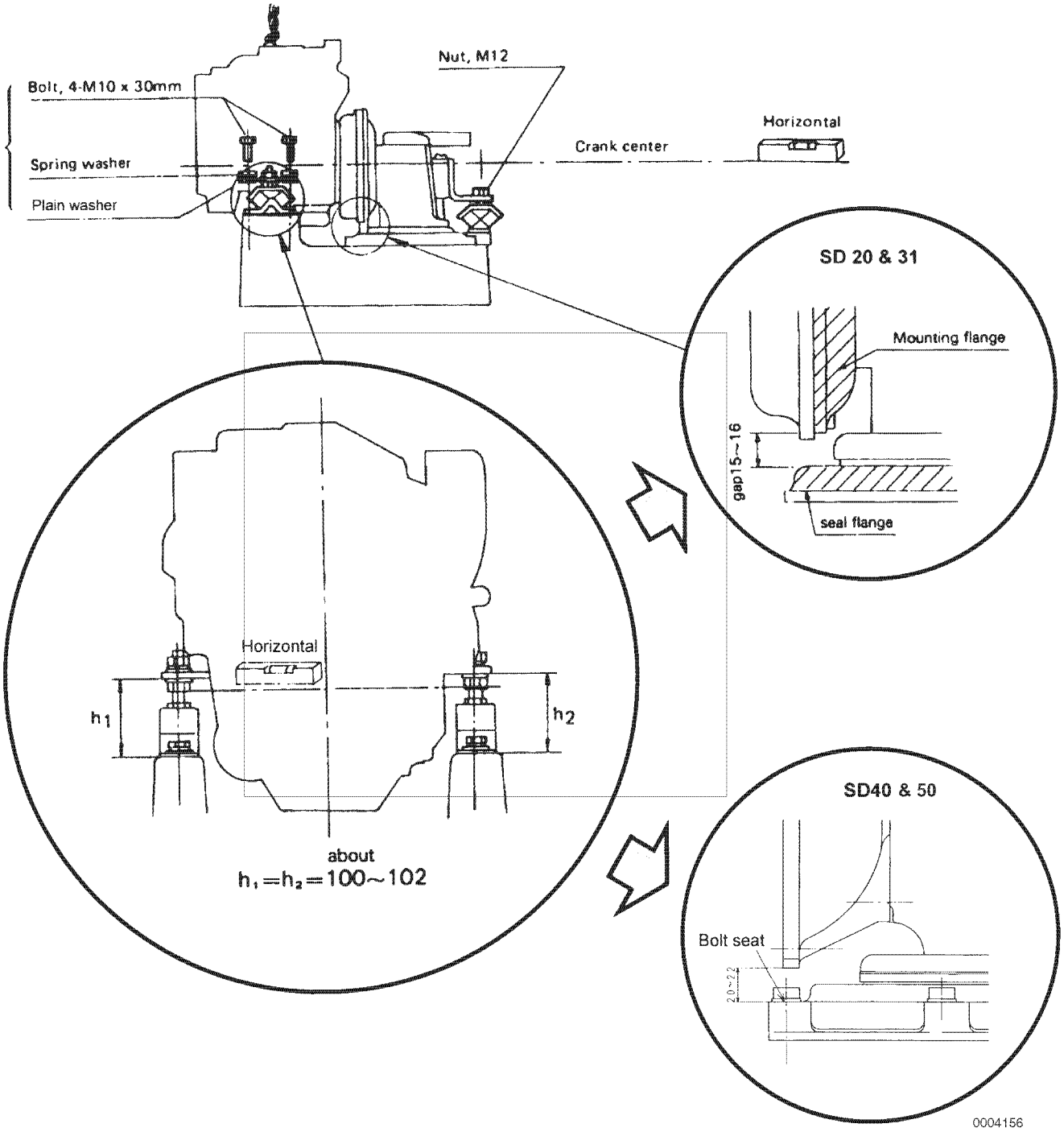

Figure 7-18

13. Adjust the jack-nuts on the engine mounts until the engine and drive are horizontal in all directions **(Figure 7-18)**.

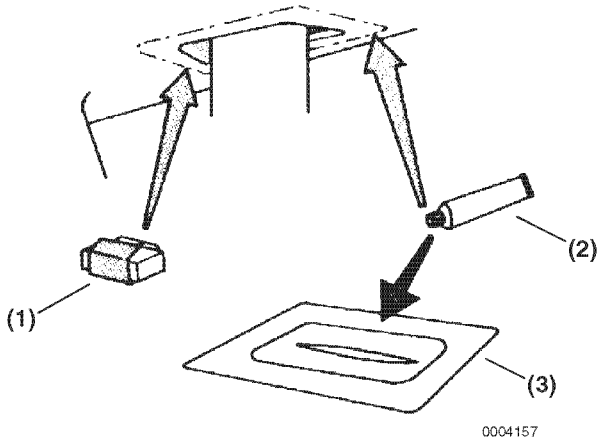

Figure 7-19

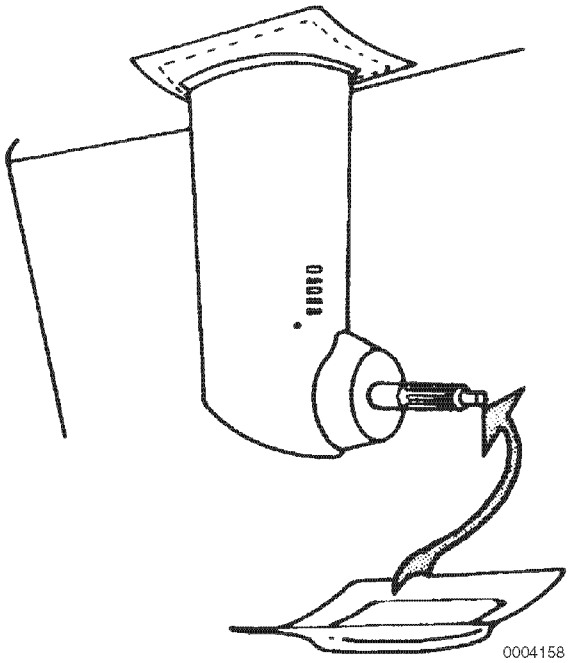

Figure 7-20

14. Clean the lower shield mounting area with sandpaper **(Figure 7-19, (1))** to ensure a good bond.
15. Apply a suitable adhesive **(Figure 7-19, (2))** to the rubber gasket **(Figure 7-19, (3))** and secure in place **(Figure 7-20)**.
16. Allow the adhesive to thoroughly dry and then check the rubber gasket to be sure it is securely and permanently bonded to the hull.

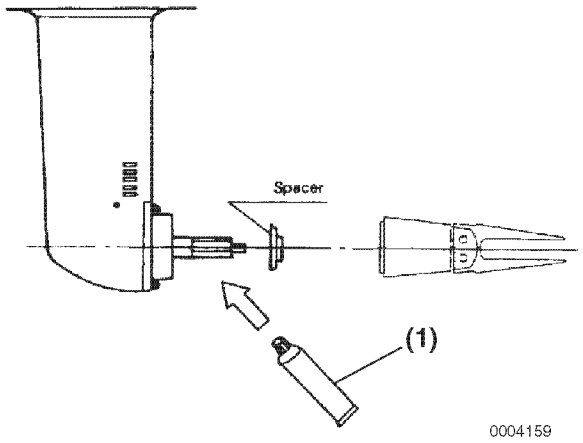

Figure 7-21

IMPORTANT

Never install a propeller without a rubber hub. Damage to the propeller shaft, bearings, and gears of the drive unit may result in case of impact with an underwater object.

Note: Functionality may decrease if non-standard hardware is used, such as a line cutter in place of the spacer.

17. Apply grease **(Figure 7-21, (1))** to the propeller shaft.
18. If installing a folding-blade propeller, refer to the propeller manufacturer's documentation for proper installation.

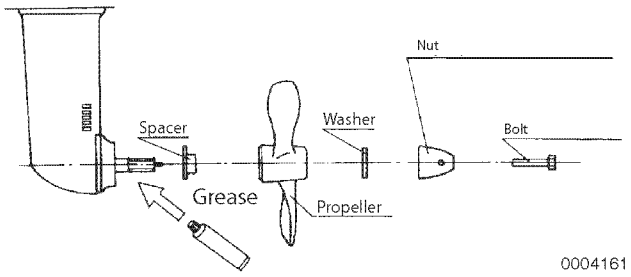

Figure 7-22

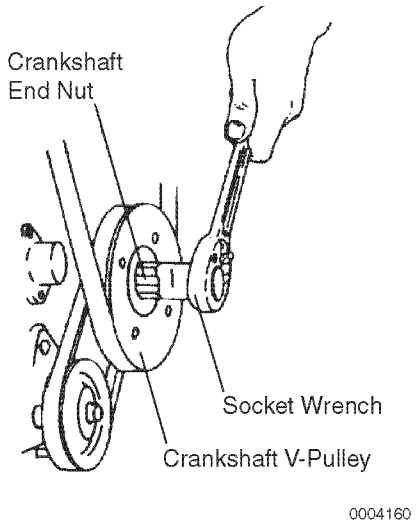

Figure 7-23

Note: To prevent the propeller shaft from turning while tightening the center bolt, use a socket wrench on the crankshaft V-pulley.

19. If installing a fixed-blade propeller, tighten the nut to specification. Engage the shift lever in forward gear and hold the crankshaft using a socket wrench **(Figure 7-19)**.
20. Tighten the M8 x 75 center bolt to specification.

Fitting for Fixed Propeller (2-Blade)

Item	Model	Torque
M8 Bolt	-	1.1 - 1.5 kgf/m (95 - 130 in.lb)
M10 Bolt	-	2.6 - 3.0 kgf/m (226 - 260 in.-lb)
Fixed-Blade Propeller Nut	SD20 SD31	6.0 - 7.0 kgf/m (43 - 51 ft-lb)
	SD40 / 50	8.0 - 10.0 kgf/m (58 - 72 ft-lb)

For details of propeller installation, refer to the propeller installation manual provided by the manufacturer.

IMPORTANT

When installing ALCO Folding Propeller:

For the sail drive, be sure to use the folding propeller which is provided with the rubber bushing. If a propeller without rubber bushing is used, the shaft, bearing, and gears of the sail drive will be damaged.

The spacer must be installed to avoid damage to the sail drive.

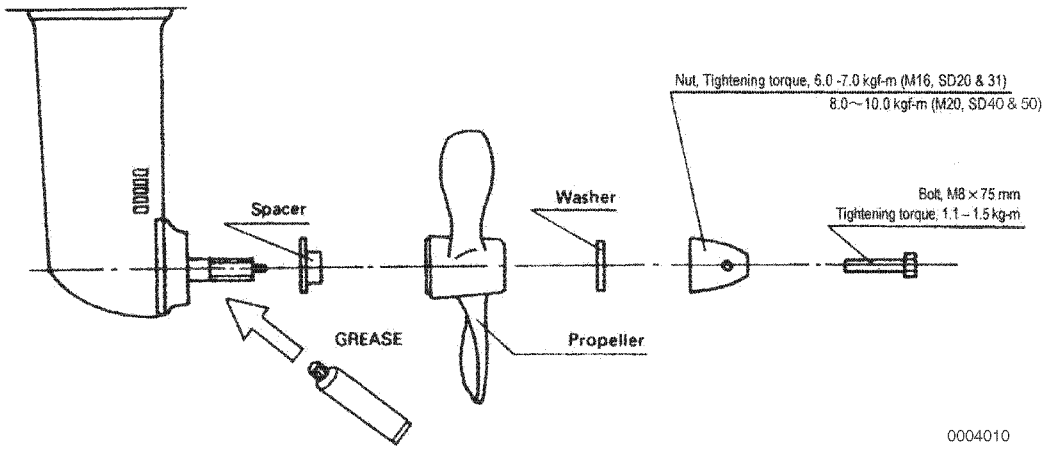

Figure 7-24

Locking Procedure for Fixed Propeller Nut (Optional): Move the shift lever to forward and hold the crankshaft V-pulley clamp nut with a wrench to stop the rotation. Tighten the nut to specification.

Sail Drive	Torque
SD20	6 - 7 kgf-m (59 - 69 N·m) (43 - 51 in.-lb)
SD40 and SD50	8 - 10 kgf-m (79 - 98 N·m) (58 - 72 in.-lb)

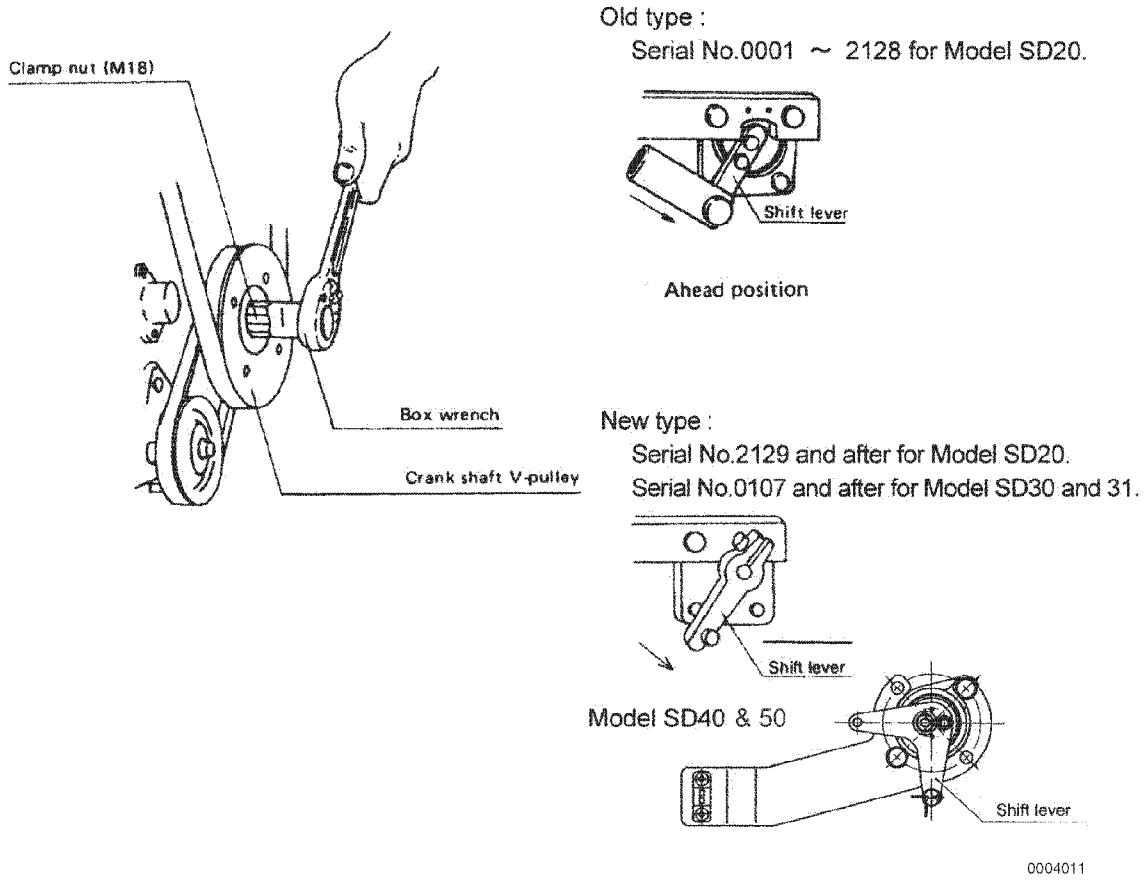

Figure 7-25

Recommended Propeller Size (Maximum)

Model	Folding-Type Diameter mm (in.)	2-Blade, Fixed Type Diameter mm (in.)	Applicable Model
1GM10C	355 (14)	355 (14)	SD20
2GM20C	380 (15)	405 (16)	
3GM30C	405 (16)	420 (16.5)	
3YM30	405 (16)	420 (16.5)	
3JH2CE	405 (16)	420 (16.5)	SD31
3JH2-TCE	420 (16.5)	420 (16.5)	
3JH3CE	405 (16)	420 (16.5)	
4JH2CE	420 (16.5)	420 (16.5)	
4JH3CE	420 (16.5)	420 (16.5)	
3JH3CE	457 (18)	457 (18)	SD40 SD50
4JH3CE	457 (18)	457 (18)	
3JH4E	457 (18)	457 (18)	

IMPORTANT

Precautions for matching the propeller:

Be sure to confirm matching of the propeller in a sea trial.

Execute a propeller matching on the basis of the propeller shaft rated output (continuous rating at propeller shaft). Ninety-five percent of the engine rated output (continuous rating at crankshaft) becomes the propeller shaft rated output (continuous rating at propeller shaft). The propeller shaft output becomes 95% of the engine rated output (continuous rating at crankshaft) in consideration of mechanical efficiency 95% of the sail drive.

In the case of propeller calculation, add an additional 5% as the sea margin to the aforementioned matching point. That is, 95% of the propeller shaft rated output (continuous rating at propeller shaft) becomes the best propeller matching. Note about the sea margin: In actual navigation, there is an increase in resistance due to the waves, wind and fouling of the hull and moreover a drop in the efficiency due to fouling of the propeller. Consequently, in the case of propeller calculation, it is necessary to allow the engine output to have some margin. For that reason, it is necessary to add the sea margin of 5% at minimum.

Installing Remote Control System

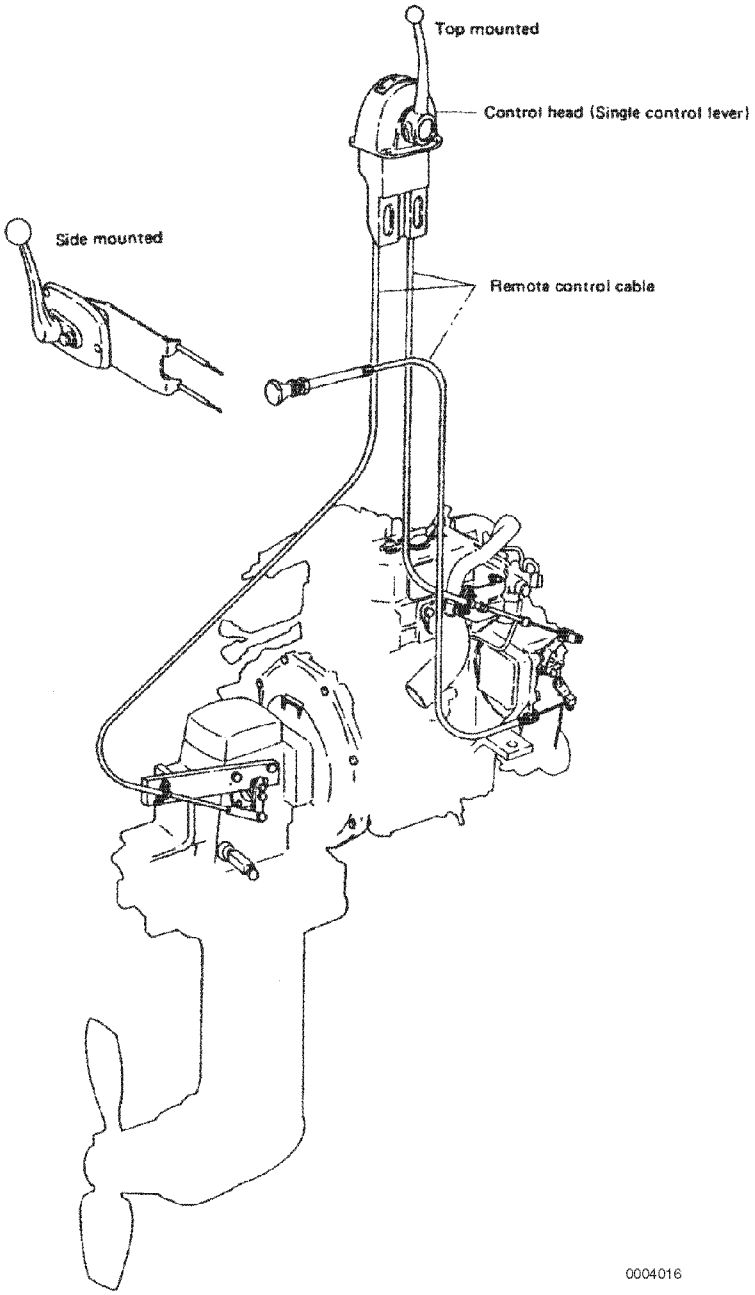

Figure 7-26

IMPORTANT

Do not use a two-lever control head. Use a single-lever control head to prevent high-speed engagement from occurring.

If the clutch is engaged while using a two-lever control head, and the rotating speed of the engine is high, the shaft and gears of the sail drive will be damaged.

Connecting the Remote Control Cable

Connect the cable (MORSE 33C or equivalent) with a spring joint or pivot. Crank the engine slowly, and while shifting the control lever of the control head through NEUTRAL - ASTERN - AHEAD - NEUTRAL, confirm the following:

1. Are the lever engagements to astern and ahead smooth?
2. Does the stopper work at both astern and ahead?
3. When the stopper is working does the shaft of the spring joint project or is it indented at the astern position? The spring joint absorbs shock on astern and ahead engagement; adjust the cable connection so that the projected distance and the indented distance of the spring joint shaft are the same except for NEW TYPE and SD40 and 50.

IMPORTANT

For the control head, use a single control lever with a 70 mm (2.75 in.) travel wire.

If the cable is not connected correctly, additional strength is required to engage and disengage the operation lever, and insufficient engagement of the lever or malfunctioning of the stopper may occur.

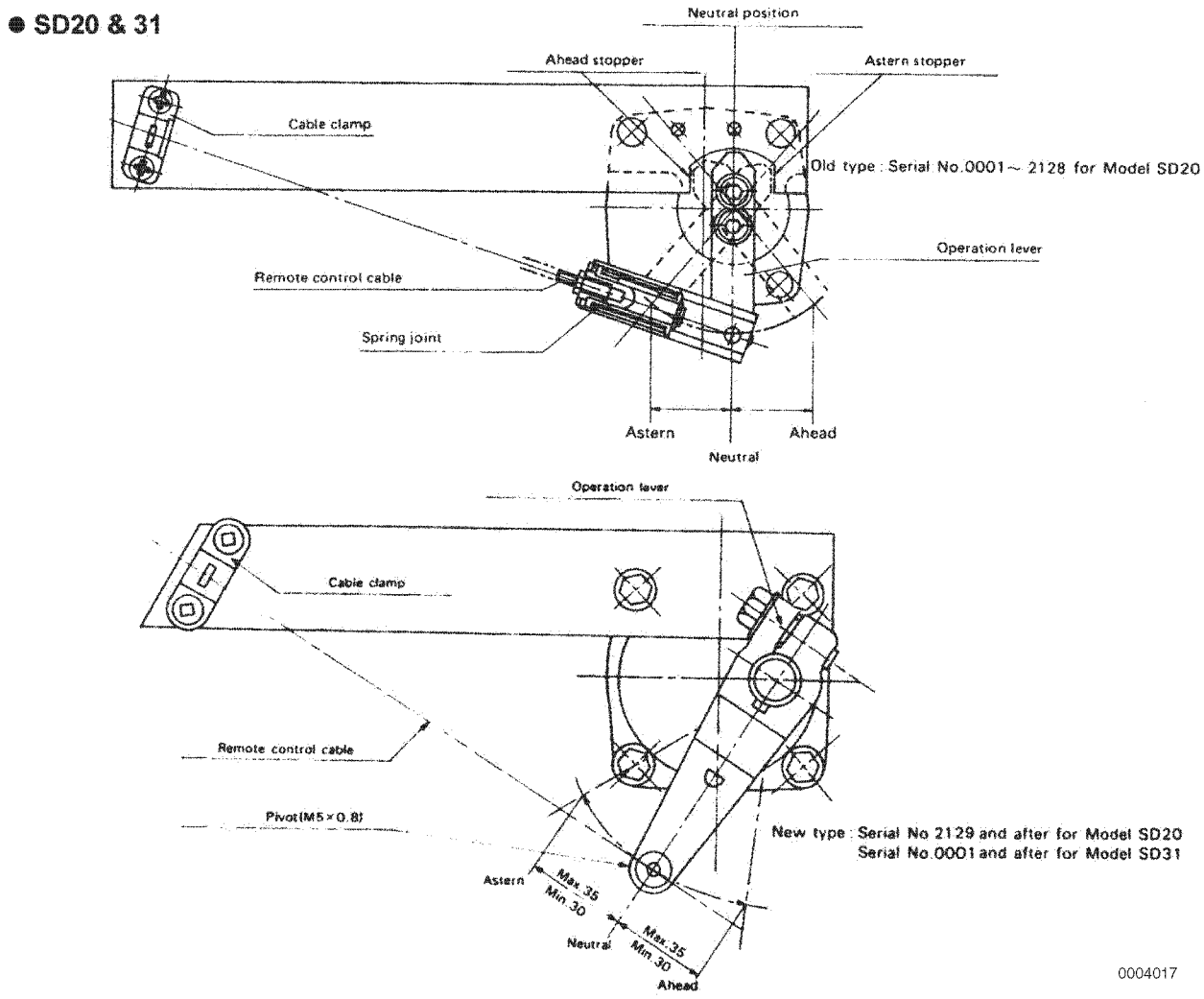
● SD20 & 31
Neutral position
Ahead stopper
Astern stopper
Cable clamp
Old type : Serial No.0001～ 2128 for Model SD20
Operation lever
Remote control cable
Spring joint
Astern
Ahead
Neutral
Operation lever
Cable clamp
Remote control cable
Pivot(M5×0.8)
New type : Serial No 2129 and after for Model SD20
Serial No.0001 and after for Model SD31
Astern
Max.35
Min.30
Neutral
Max.35
Min.30
Ahead
0004017

Figure 7-27

SD40 and 50

Models SD40 and 50 allow for rerouting of cables by directing the cable clamp up by 90° **(Figure 7-28, (B))**. The standard direction is as shown in **(Figure 7-28, (A))**, but reroute the cables, if necessary, to facilitate cable routing in accordance with the mounting position of the control head.

Figure 7-28 shows configuration as shipped from the factory.

To change the direction of the cable clamp:

1. Remove two M8 bolts and spring washer.
2. Rotate the cable clamp up by 90°.
3. Reinstall the two M8 bolts and spring washer as shown. Tighten to 1.5 ± 0.1 kgf-m (14.7 ± 0.1 N·m) (130 ± 8.7 in.-lb).
4. Remove split pin at the back of the pivot on the shift lever and install the pivot from position (A) **(Figure 7-28, (A))** to position (B) **(Figure 7-28, (B))**.

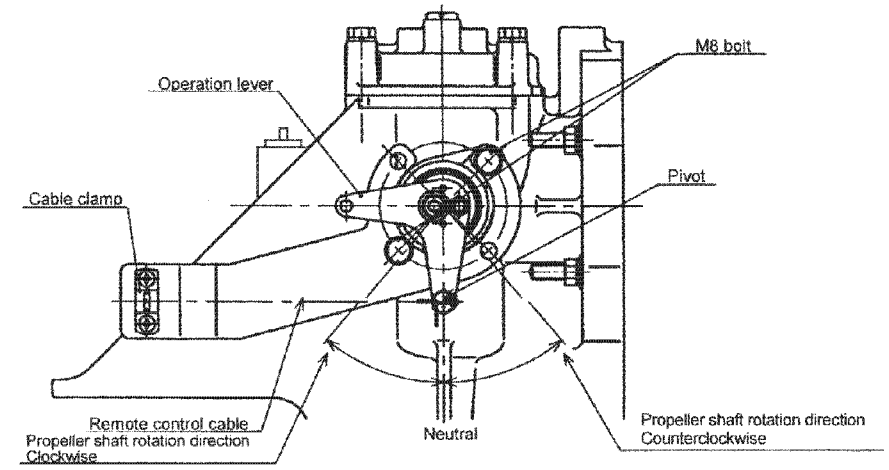

Fig. A Standard

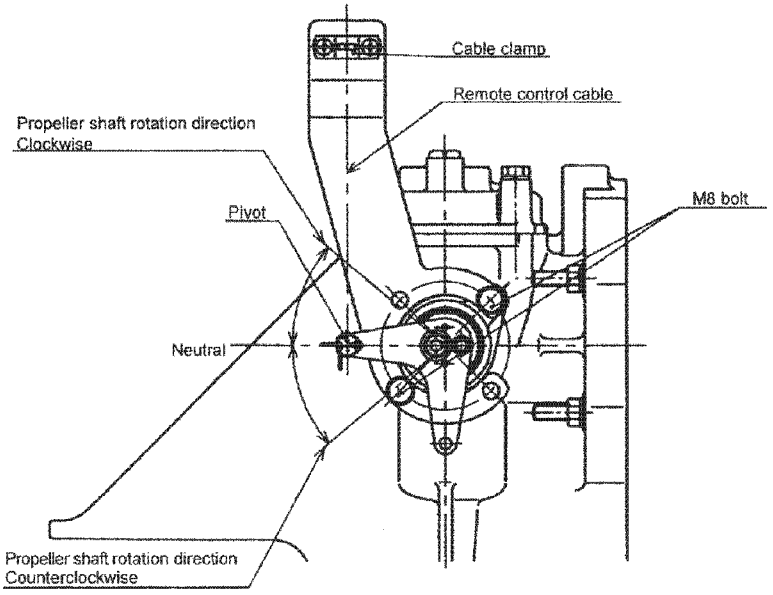

Fig. B When shift cable mounting board is directed upward by 90°

0004018

Figure 7-28

Electrical Wiring

1. For the sail drive rubber seal switch, connect the black, white and red wires on the engine side.
2. Connect the amplifier coupler between the wire harness coupler and extension cable coupler on the engine side.

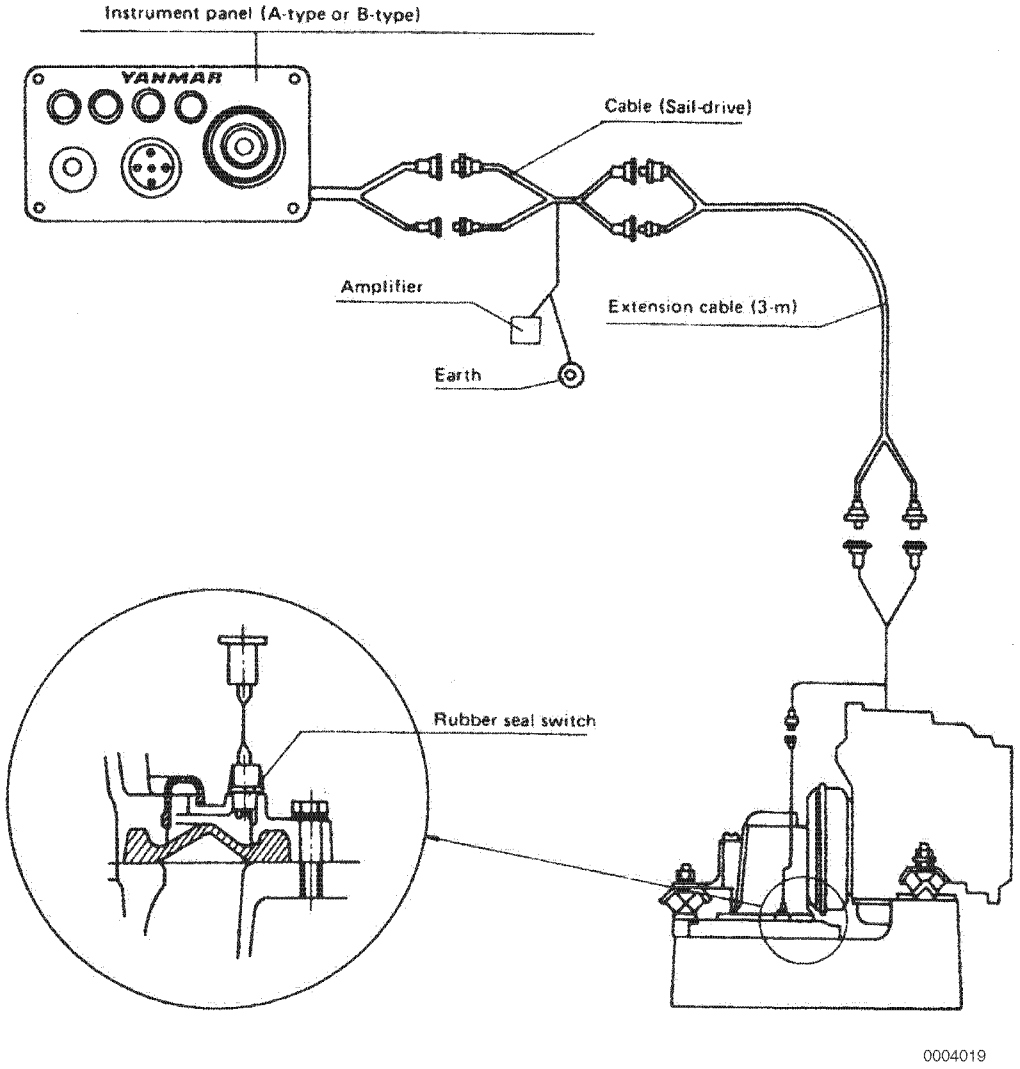

Figure 7-29

Section 8

APPENDIX A

Page

Conversion Table 8-3
Weights and Measures 8-3

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CONVERSION TABLE

Weights and Measures

1. Linear distance

Unit	mm	cm	m	km	in.	ft	yd	mile
mm	1	0.1	0.001	0.0000001	0.03937	0.0032808	0.0010936	6.214×10^{-7}
cm	10	1	0.01	0.0001	0.3937	0.032808	0.010936	6.214×10^{-6}
m	1000	100	1	0.001	39.37	3.28083	1.0936	6.214×10^{-4}
km	...	100000	1000	1	39370	3280.83	1093.61	0.62137
in.	25.40	2.540	0.02540	2.54×10^{-5}	1	0.0833	0.02778	1.578×10^{-5}
ft	304.8	30.48	0.3048	3.048×10^{-4}	12	1	0.3333	1.894×10^{-4}
yd	914.4	91.44	0.9144	9.144×10^{-4}	36	3	1	5.682×10^{-4}
mile	1609347.0	160934.70	1609.35	1.60935	63360	5280	1760	1

2. Area

Unit	mm^2	cm^2	m^2	Are	Hectare	km^2
mm^2	1	0.01	1.0×10^{-6}	1.0×10^{-8}	1.0×10^{-10}	1.0×10^{-12}
cm^2	100	1	0.0001	1.0×10^{-6}	1.0×10^{-8}	1.0×10^{-10}
m^2	1.0×10^{6}	10000	1	0.1	0.0001	1.0×10^{-6}
Are	1.0×10^{8}	1.0×10^{6}	100	1	0.01	0.0001
Hectare	1.0×10^{10}	1.0×10^{8}	10000	100	1	0.01
km^2	1.0×10^{12}	1.0×10^{10}	1.0×10^{6}	10000	100	1
$in.^2$	645.2	6.452	6.452×10^{-4}	6.452×10^{-6}	6.452×10^{-8}	6.452×10^{-10}
ft^2	92900	929	0.09290	9.290×10^{-4}	9.290×10^{-6}	9.290×10^{-8}
yd^2	836100	8361	0.8361	0.008361	8.361×10^{-5}	8.361×10^{-7}
Acre	4.04684×10^{9}	40468700	4046.87	40.47	0.4047	4.047×10^{-3}
$mile^2$	2.589999×10^{12}	2.589999×10^{10}	2589999	25899.99	259.0	2.590

Unit	$in.^2$	ft^2	yd^2	Acre	$mile^2$
mm^2	0.00155	1.0764×10^{-5}	1.19599×10^{-6}	2.471×10^{-10}	3.861×10^{-13}
cm^2	0.154999	0.0010764	1.19599×10^{-4}	2.471×10^{-8}	3.861×10^{-11}
m^2	1549.99	10.7639	1.19599	2.471×10^{-4}	3.861×10^{-7}
Are	154999	1076.39	119.6	0.02471	3.861×10^{-5}
Hectare	15499969	107639	11959.9	2.471	0.003861
km^2	...	10763867	1195985	247.1	0.3861
$in.^2$	1	0.006944	7.716×10^{-4}	1.594×10^{-7}	2.491×10^{-10}
ft^2	144	1	0.11111	2.296×10^{-5}	3.587×10^{-8}
yd^2	1296	9	1	2.066×10^{-4}	3.228×10^{-7}
Acre	6272640	43560	4840	1	0.001563
$mile^2$	...	27878400	3097600	640	1

3. Volume

Unit	cm^3	m^3	L	kL	$in.^3$	ft^3	yd^3	gal (liquid) (USA)
cm^3	1	1.0×10^{-6}	0.001	1.0×10^{-6}	0.06102	3.531×10^{-5}	1.308×10^{-6}	2.642×10^{-4}
m^3	1000000	1	1000	1	61020	35.31	1.308	264.2
L	1000	0.001	1	0.001	61.02	0.03531	0.001308	0.2642
kL	1000000	1	1000	1	61020	35.31	1.308	264.2
$in.^3$	16.39	1.639×10^{-5}	0.01639	1.639×10^{-5}	1	5.787×10^{-4}	2.143×10^{-5}	0.004329
ft^3	28320	0.02832	28.32	0.2832	1728	1	0.03704	7.48055
yd^3	764500	0.7645	764.5	0.7645	46660	27	1	201.974
gal (liquid) (USA)	3785	0.003785	3.785	0.003785	231	0.1337	0.004951	1

4. Weight

Unit	kg	oz	lb	(2000 lb) nt	(2240 lb) gt	mt
kg	1	35.2740	2.20462	0.001102	9.842×10^{-4}	0.001
oz	0.02835	1	0.06250	3.125×10^{-5}	2.790×10^{-5}	2.835×10^{-5}
lb	0.45359	16	1	0.00050	0.89286	0.90719
nt	907.185	32000	2000	1	0.89286	0.90719
gt	1016.05	35840	2240	1.12	1	1.01605
mt	1000	35274	2204.6	1.10231	0.98421	1
[Remarks] mt (metric), nt (USA), gt (UK)						

5. Weight per Unit Length

Unit	g/cm	kg/m	in.-lb	ft-lb	yd-lb	nt/mile	gt/mile
g/cm	1	0.10	0.00560	0.06720	0.20159	0.17740	0.15839
kg/m	10	1	0.0560	0.67197	2.0159	1.7740	1.58393
in.-lb	178.579	17.8579	1	12	36	31.680	28.2857
yd-lb	4.96054	0.49605	0.02778	0.333	1	0.8800	0.78571
nt/mile	5.63698	0.56370	0.03157	0.37879	1.13636	1	0.89286
gt/mile	6.31342	0.63134	0.03535	0.42424	1.27273	1.12	1
[Remarks] nt (U.S.), gt (U.K.)							

6. Pressure

Bar	kgf-cm^2	in.^{2}-lb	gt/ft^2	Standard atmo-spheric pressure (760 mm)	Mercury column height at 0°C		Mercury column height at 15°C	
					m	in.	m	in.
1	1.0204	14.51	0.9330	0.9869	0.75055	29.55	10.213	33.51
0.98	1	14.22	0.9144	0.9672	0.7355	28.96	10.009	32.84
0.06895	0.07031	1	0.06429	0.06800	0.05171	2.036	0.7037	2.309
1.072	1.094	15.56	1	1.058	0.8044	31.67	10.95	35.91
1.0133	1.0340	14.706	0.9454	1	0.76052	29.94	10.35	33.90
1.3324	1.3595	19.34	1.243	1.3149	1	39.37	13.61	44.64
0.03384	0.03453	0.4912	0.03158	0.03340	0.02540	1	0.3456	1.134
0.09791	0.09991	1.421	0.09136	0.09663	0.07349	2.893	1	3.281
0.02984	0.03045	0.4331	0.02785	0.02945	0.02240	0.8819	0.3048	1
[Remarks] gt (UK)								

7. Density

Unit	g/cm^3	kg/m^3	in.^{3}-lb	ft^3-lb	yd^3-lb	gal (liquid) (USA)
g/cm^3	1	1000	0.03613	62.4283	1685.56	8.34545
kg/m^3	0.001	1	3.613×10^{-5}	0.06243	1.68556	8.345×10^{-3}
in.^{3}-lb	27.6797	27679.7	1	1728	46656	231
ft^3-lb	0.01602	16.0184	5.787×10^{-4}	1	27	0.13368
yd^3-lb	5.933×10^{-4}	0.59327	2.143×10^{-5}	0.03704	1	4.651×10^{-3}
gal (liquid) (USA)	0.11983	119.826	4.329×10^{-3}	7.48052	201.974	1

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Section 9

APPENDIX B

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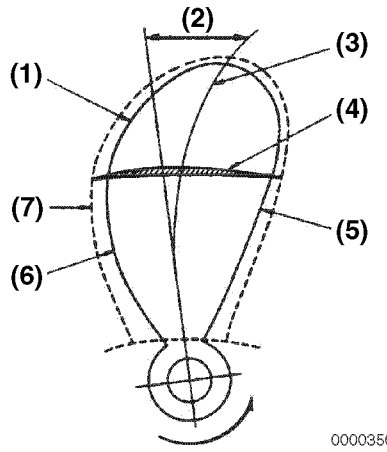
Definition of Terms - Engines and Boats

Engine / Boat Term	Definitions
Acceleration	The time required to bring a vessel from one speed to a faster speed.
Accelerometer	An instrument used to measure acceleration.
Aft	Toward the rear or stern of the vessel.
Alignment Device	A type of hitching device that allows for one-person hitching of a tow vehicle and trailer.
Amidship	Center or middle of the vessel.
Angle Drive	A drive configuration is sometimes called the down-angle drive system. The output shaft of the marine gear is inclined at 7-10° to the crankshaft.
Bilge	The lowest section of a boat's floor on either side of the keel where water is likely to collect. The area of the hull that sits below the waterline.
Bilge Blower	Exhaust fan used to ventilate gasses from the bilge.
Bilge Pump	A mechanical, electrical or manually operated device used to pump water from the bilge.
Blower	Exhaust fan used to ventilate gasses from the engine compartment, galley, or head.
Bow	The front of a vessel.
Cabin	Living quarters on a vessel.
Cabin Cruiser	A cruising vessel with living quarters on board.
Cargo	Luggage or material other than fuel, food and consumable provisions on board. Cargo has mass and contributes to the vessel's displacement.
Center Line	A lengthwise imaginary line which runs fore and aft with the vessel's keel.
Cockpit	An opening in the deck of the boat from which the boat is handled or the recessed area in the deck of the boat in which the crew works.
Continuous Output	The peak power that an engine can develop for an extended period of time at any given rpm.
Displacement	The weight of water displaced by the total mass of a vessel.
Displacement Hull	Displacement hulls are driven through the water, rather than being pushed up on top of the water.
Down Drive	See ***Angle Drive.***
Duty Cycle	The sea time imposed on the engine and hull during a single use.
Economy	The cost of exhausting the vessel's fuel capacity and full range.
Engine	Machine used to convert various forms of energy into mechanical force or motion.
Engine Bed	Structure that supports the boat's engine.
Engine Efficiency	The fuel consumption as it relates to the hull performance characteristics.
Engine Intake Air	Air provided by the air intake system and used by the engine during the combustion process.
Engine Mounts	Flexible supports, usually rubber, that are between the lugs on the engine and engine bed.
Engine Room	Space in the vessel for the engine and other equipment. It is generally located aft, but can also be amidships for some inboard installations.
Engine Room Ventilation	The process of replacing air in the engine room with fresh air from outside the vessel.
Flexible Engine Mounts	A system of engine mounts that allow limited movement of the engine relative to the rest of the vessel. Flexible mounts reduce hull vibration.
Fore	Toward the front or bow of the vessel. Opposite of aft.
Gear Reduction	A marine gear with a reduction ratio between the engine and the propeller.

Engine / Boat Term	Definitions
Horsepower (hp)	A unit of power. It can also be expressed as kilowatts.
Hull	The body of the vessel.
Hull Efficiency	The hull power requirements as they relate to the hull performance characteristics.
Hull Speed	The speed at which a hull can no longer increase with added power.
Jig	A device use to stabilize and direct a tool while cutting through a material.
Kilowatt (kW)	A unit of power. It can also be expressed as horsepower.
Kilometers Per Hour (kM/h)	A unit of speed. It can also be expressed as knots or mph.
Knot	Nautical miles per hour. A unit of speed. It can also be expressed as kMh or mph
Marine Gear	That component of the propulsion system that transmits and controls power from the engine to the propeller.
Maximum Output	The peak power that an engine can develop for a short duration at any given rpm.
Miles Per Hour (mph)	A unit of speed. It can also be expressed as kMh or knots.
Output De-Rating	The adjusted power output based on parasitic losses imposed by other equipment.
Parallel Drive	The output shaft of a marine gear that is parallel to the crankshaft.
Pickup	A vessel's capacity for acceleration.
Pilot Hole	An initial hole that is drilled using a smaller bit in order to make it easier to drill using a larger bit.
Pitch	The forward-to-aft motion that lowers the bow or stern portion of the vessel near the waterline.
Planing Hull	A hull that is driven up on top of the water rather than being driven through the water.
Pleasure Vessel	A vessel used for recreational purposes, usually having a light-duty cycle.
Port	(1) The left side of a vessel when facing the bow. (2) A destination or harbor.
Propeller	The component that transfers marine gear power to the water, resulting in vessel motion.
Roll	The side-to-side motion that lowers the port or starboard portion of the vessel near the waterline.
Revolutions per Minute (rpm)	Unit of measure. Measures the rotational speed of the motor's spindle.
Sailboat	A vessel that is driven primarily by the wind.
Scoop Strainer	Device placed on the seawater intake that prevents objects, such as debris or seaweed, from entering and clogging the engine's cooling system.
Screw	See ***Propeller.***
Seaworthy	A term used to describe the degree to which a vessel can tolerate adverse weather conditions.
Semi-Displacement Hull	Semi-displacement hull designs represent a compromise in performance between planing and displacement hull designs.
Single-Screw Configuration	A vessel with one propeller.
Ski Boat	A power vessel designed to pull multiple water skiers at a constant speed in a relatively straight line.
Snubber-Style Mount	Style of engine mount that uses a cushioning device, usually rubber, to decrease the amount of engine vibration.
Starboard	The right side of the vessel when looking towards the bow.
Stern	The back of the vessel.
Stern Tube	The bearing that supports the propeller shaft where it emerges from the hull.

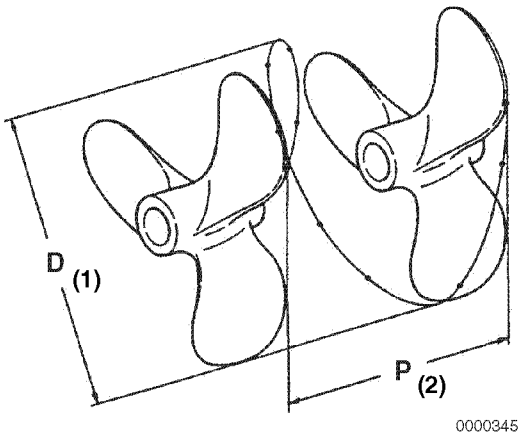
Engine / Boat Term	Definitions
Strainer	See ***Scoop Strainer***.
Stringer	A lengthwise stiffener for the side of a boat.
Three-Way Cock	A valve with three ports.
Torque	The theoretical force required to move a shaft with a given length of leverage.
Transmission	See ***Marine Gear***.
Twin-Screw Configuration	A vessel with two propellers.
User's Performance Requirements	The vessel performance characteristics demanded by the user or owner.
V-Drive	The output shaft of the marine gear forms a V-shape with the input shaft.
Vessel Purpose	Placing a vessel into either pleasure or work categories.
Work Vessel	A vessel used for commercial or government purposes, usually having a heavy-duty cycle.
Yaw	The change of direction or position, port-to-starboard or starboard-to-port.

Definition of Terms - Propellers



1– Projected Outline
2– Skewback
3– Line of Maximum Thickness
4– Cross-Section of Blade With Round Back
5– Trailing Edge
6– Leading Edge
7– Developed Outline

Figure 9-1



1– D = Diameter **2 – P = Pitch**

Figure 9-2

Propeller Term	Definitions
Area	The area or the disk area is the space enveloped by the circle constructed by the blade tips.
Blade Back	Also called the suction or negative pressure side. The blade back is the face of the blade facing the vessel that creates suction by drawing water into the propeller when it is moving forward.
Blade Face	Also called the pushing or pitch face. The blade face is the face of the area of the blade facing away from the vessel that creates forward thrust by pushing water away from the propeller.
Blade Numbering	The blade located at the keyway is considered blade number 1. Blade numbers 2, 3, etc. are determined by starting from blade 1 and counting clockwise (on right-hand propellers) or counterclockwise (on left-hand propellers).
Blade Root	Also called the filet. The blade root is the base of the blade that extends out from the hub. It is also the thickest section of the blade to provide structural rigidity.
Blade Thickness	The blade is thickest at the root and becomes thinner as it extends outward toward the tip. It takes less power to push a thinner blade through water than it does to push a thicker blade A thinner blade has less surface area to create drag.
Blade Tip	The point on the propeller that reaches the farthest distance from the center of the hub.
Camber	The curvature of the line of maximum thickness that runs from the hub to the blade edge.

Propeller Term	Definitions
Cavitation	Cavitation is the phenomenon that occurs when the force of the spinning blades causes an extreme reduction of pressure on the back side of the propeller and vaporizes or "boils" the water around it. Cavitation results when the propeller is spinning but produces relatively little thrust due to slippage, causing microscopic air bubbles to impact and damage the blades. There are numerous causes of cavitation, such as: physical damage to blades, mismatching of propeller style to the engine or application, incorrect propeller pitch, or extremely high rates of speed. **Not to be confused with ventilation.**
Cleaver Propeller	Cleaver propellers are for high performance vessels used in competitive racing and ski boat applications. They perform well at high rpm through step-up marine gears. The blades are typically heavily skewed and raked aft. Cleaver propellers provide top end acceleration performance through the full rpm range and typically have large blade area for greater thrust.
Controllable Pitch	Also called adjustable pitch. Controllable pitch allows blade angle adjustments while underway. Adjustments increase fuel efficiency, or speed and performance. Propellers with adjustable pitch have a hollow shaft.
Cross-Section of Blade with Round Back **(Figure 9-1, (4))**	The profile of a cross-section of the propeller blade at the thickest portion.
Cup	The cup is the small curved portion on the trailing edge of the blade. The cup helps the blade to gain a better grip on the water, reduces ventilation and slipping. It provides increased lift capability. Cupping typically increases the overall pitch of a propeller by 12.7 to 25.4 mm (0.5 to 1.0 in.).
Developed Outline **(Figure 9-1, (7))**	A theoretical dimensional limit that represents the maximum distortion when the propeller is operating.
Diameter **(Figure 9-2, (D))**	The distance across the imaginary circle constructed by the blade tips as the propeller is spinning.
Folding Propeller	Propeller for sailboats that is able to collapse when the vessel is operating under wind power in order to reduce the drag created by the propeller blades. By using a folding propeller versus a fixed propeller, a sailboat can effectively reduce the amount of drag created by the propeller by up to 35%.
Hub	The hub is the section at the center of the propeller from which the blades extend. It attaches to the engine shaft. Hubs can be cylindrical, radial, conical or barreled.
Keyway	The keyway is the thin rectangular groove milled into the hub that carries the key and prevents the propeller from slipping on the shaft.
Leading Edge **(Figure 9-1, (6))**	The leading edge is the edge of the propeller blade closest to the boat that starts at the hub and extends to the blade tip. It is the first part of the blade to cut through the water when the vessel is moving forward.
Left-Hand Propeller	Viewed from the aft, the left-hand propeller rotates counterclockwise when providing forward thrust.
Line of Maximum Thickness **(Figure 9-1, (3))**	That portion of the propeller that represents the thickest section.
Over-Hub Exhaust	Over-hub exhaust exits the vessel and is directed over the blades and hub.
Pitch **(Figure 9-2, (2))**	Assuming a theoretical 100% efficient propeller and hull, pitch is defined as the distance that a propeller advances a vessel during one complete 360° revolution. It is expressed in linear distance. Propellers are manufactured in constant pitch or progressive pitch configurations. Constant pitch propellers have a constant pitch throughout the radial length of the propeller blades. Progressive pitch propellers have a relatively low pitch at the leading edge of the blades which increases toward the trailing edge. **Not to be confused with Pitch Angle.**

Propeller Term	Definitions
Pitch Angle	Pitch angle is the angle of the blade face as it moves along the pitch line in relation to the plane of rotation. Pitch angle decreases from the blade root to the tip in order to maintain a constant pitch. **Not to be confused with Pitch.**
Projected Outline **(Figure 9-1, (1))**	A theoretical dimensional limit that represents the maximum distortion when the propeller is operating.
Rake	Rake is defined as the blade angle relative to the center of the shaft. It is expressed in degrees. High-performance propellers that are raked aft give vessels greater lift without ventilation. Propellers are manufactured in forward, aft, parabolic and straight rake configurations. A forward or negative rake is slanted toward the forward end of the hub. An aft rake is slanted toward the aft end of the hub. A parabolic rake is slightly off-center and gives the blade a spoon-like appearance. A straight rake is flat across the blade.
Right-Hand Propeller	Viewed from the aft, the right-hand propeller rotates clockwise when providing forward thrust.
Rotation	The clockwise or counterclockwise motion of the propeller as it provides forward thrust.
Skew or Skewback **(Figure 9-1, (2))**	Skew is the degree to which the contour of the blade is swept aft. The more swept back and asymmetrical a blade is, the higher the level of skew.
Slip	Slip is the difference between that actual distance that the propeller travels in one revolution and the theoretical distance (pitch) that it should travel. A properly matched propeller will only have a slip of 10 to 20%.
Screw	Another term for propeller.
Through-Hub Exhaust	The through-hub exhaust is a hollow barrel within the hub that channels the exhaust through the hub and out the rear of the propeller. Through-hub exhaust reduces the chance of exhaust being drawn into the blades (ventilation).
Track	Track is the spread between the individual blade rake and the other blade rakes.
Trailing Edge **(Figure 9-1, (5))**	The trailing edge is the edge of the propeller blade that extends from the blade tip to the hub. It is where water exits the blade.
Variable Pitch	Variable pitch propellers are those with skew and cup properties that change the pitch depending on the rpm. The pitch is higher at the trailing edge and blade tip, and lower at the leading edge and hub.
Ventilation	Ventilation occurs when air from the water's surface or engine exhaust are drawn into the propeller blades, causing the rpm to increase and thrust to decrease. **Not to be confused with Cavitation.**